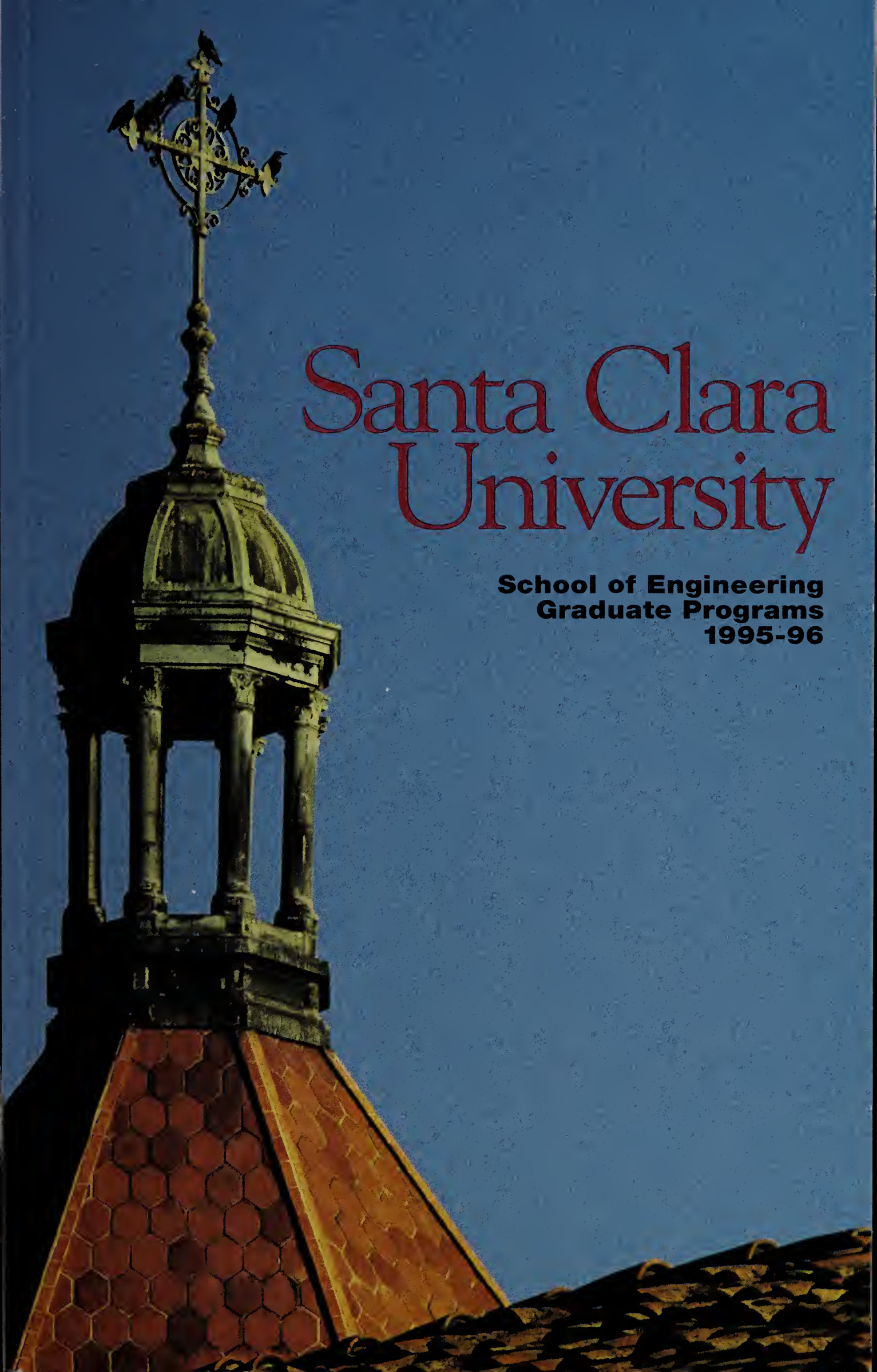

Santa Clara University

School of Engineering
Graduate Programs
1995-96

For information:

School of Engineering
Graduate Education
Santa Clara University
Santa Clara, California 95053
408-554-4600

Santa Clara University reserves the right to make program, regulation, and fee changes at any time without prior notice. The University strives to assure the accuracy of the information in this bulletin at the time of publication. However, certain statements contained in this bulletin may change or need correction.

Nondiscrimination Policy

Santa Clara University does not discriminate on the basis of race, color, national and/or ethnic origin, sex, marital status, sexual orientation, disability, religion, veteran's status, or age in the administration of any of its educational policies, admissions policies, scholarship and loan programs, athletics, or employment-related policies, programs, and activities; or other University-administered policies, programs, and activities.

Inquiries regarding equal opportunity policies, the filing of grievances, or requests for a copy of the grievance procedures covering discrimination and harassment complaints should be directed to:

Conchita Franco Serri, Director
Office of Affirmative Action
SCU Title IX Compliance Officer
Walsh Administration Bldg.
Santa Clara, CA 95053
408-554-4113 or 408-554-4178

Copies of these policies and procedures are also available from Human Resource Management (408-554-4392).

SANTA CLARA UNIVERSITY

School of Engineering
Graduate Programs
1995–96

Santa Clara, California 95053

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Academic Calendar 1995–96

FALL QUARTER 1995

May 19	Friday	Last day to petition for graduate degrees to be conferred in December 1995
August 7–18	Monday–Friday	Registration period
September 4	Monday	Labor Day; administrative holiday
September 20	Wednesday	Classes begin
September 20–26	Wednesday–Tuesday	Late registration
September 27	Wednesday	Last day to change registration
October 13	Friday	Last day to submit incomplete work for spring and summer 1995 (or I becomes an F)
November 22	Wednesday	Academic holiday
November 23, 24	Thursday, Friday	Thanksgiving recess; academic and administrative holiday
November 27	Monday	Last day to withdraw from classes
December 1	Friday	Last day to petition for graduate degrees to be conferred in March 1996
December 1	Friday	Classes end
December 4–8	Monday–Friday	Fall quarter examinations
December 13	Wednesday	Fall quarter grades due
December 25, 26	Monday, Tuesday	Christmas recess; administrative holiday
December 29, January 1	Friday, Monday	New Year's recess; administrative holiday

WINTER QUARTER 1996

October 30–November 10	Monday–Friday	Registration period
January 3	Wednesday	Classes begin
January 3–9	Wednesday–Tuesday	Late registration
January 10	Wednesday	Last day to change registration
January 12	Friday	Last day to petition for graduate degrees to be conferred in June 1996

January 15	Monday	Martin Luther King Day; academic and administrative holiday*
January 19	Friday	Last day to submit incomplete work for fall 1995 (or I becomes an F)
February 19	Monday	Presidents Day; academic and administrative holiday*
March 8	Friday	Last day to withdraw from classes
March 15	Friday	Classes end
March 18–22	Monday–Friday	Winter quarter examinations
March 27	Wednesday	Winter quarter grades due

SPRING QUARTER 1996

February 8–16	Thursday–Friday	Registration period
April 1	Monday	Classes begin
April 1–4	Monday–Thursday	Late registration
April 4	Thursday	Last day to petition for graduate degrees to be conferred in August 1996
April 5	Friday	Good Friday; administrative holiday*
April 8	Monday	Last day to change registration
April 19	Friday	Last day to submit incomplete work for winter 1996 (or I becomes an F)
May 27	Monday	Memorial Day; academic and administrative holiday*
May 31	Friday	Last day to withdraw from classes
June 7	Friday	Classes end
June 10–14	Monday–Friday	Spring quarter examinations
June 16	Sunday	Graduate commencement
June 19	Wednesday	Spring quarter grades due

*Graduate engineering classes meet despite the holiday.

SUMMER SESSION 1996**

May 6–17	Monday–Friday	Registration period
June 17	Monday	Classes begin
June 17, 18	Monday, Tuesday	Late registration
July 4	Thursday	Independence Day; academic and administrative holiday
July 22–26	Monday–Friday	Summer session examinations (5-week session)
August 26–30	Monday–Friday	Summer session examinations (10-week session)
September 18	Wednesday	Last day to petition for graduate degrees to be conferred in December 1996

All dates are inclusive.

Registration dates are subject to change.

**Dates reflect 5- and 10-week sessions and are subject to change.

Engineering at Santa Clara

The undergraduate programs leading to the Bachelor of Science in Civil, Electrical, and Mechanical Engineering were first offered at Santa Clara University in 1912; the programs were accredited by the Accreditation Board for Engineering and Technology in 1937. Since that time, the following degree programs have been added: Bachelor of Science in Computer Engineering and Bachelor of Science in Engineering; Master of Science in Applied Mathematics, Civil Engineering, Computer Engineering, Electrical Engineering, Engineering, Engineering Management, and Mechanical Engineering; Engineer's Degree in Electrical Engineering and Mechanical Engineering; and Doctor of Philosophy in Computer Engineering, Electrical Engineering, and Mechanical Engineering. In addition, the School of Engineering offers a variety of certificate programs.

SCHOOL OF ENGINEERING

Terry E. Shoup *(Dean)*

At one time, engineering knowledge was passed from generation to generation in the familiar pattern of the apprenticeship. With increasingly complex applications of science, engineers turned to the universities for greater formal preparation in science and mathematics. The function of engineering is to bridge science and society; to modify nature to meet the needs of society within the restrictions dictated by social, political, and economic considerations.

The rapid expansion of knowledge and complexity in all areas of science and engineering suggests the need to both broaden the educational program and increase specialization. Both goals cannot be accomplished in four years of undergraduate study; hence, the development of the graduate program.

1

Santa Clara University

STATEMENT OF PURPOSE

Inspired by the love of God to serve society through education, continuing the commitment of the Franciscans who founded Mission Santa Clara in 1777 and the Jesuits who opened the College in 1851, Santa Clara University declares its purpose to be the education of the whole person within the Catholic and Jesuit tradition.

The University is thus dedicated to

- the preparation of students to assume leadership roles in society through an education that stresses moral and spiritual as well as intellectual and aesthetic values, seeks to answer not only "what is" but "what should be," and encourages faith and the promotion of justice;
- an uncompromising standard of academic excellence and an unwavering commitment to academic freedom, freedom of inquiry, and freedom of expression in the search for truth;
- rigorous and imaginative scholarship; excellent teaching in and out of the classroom; and educational programs designed to provide breadth and depth, to encourage the integration of different forms of knowledge, and to stimulate not only the acquisition but also the creative and humane use of knowledge;
- affirmation of its Catholic identity, respect for other religious and philosophical traditions, promotion of dialogue between faith and contemporary culture, opposition to narrow indoctrination or proselytizing, and the opportunity for worship and the deepening of religious belief;
- a community enriched by men and women of diverse backgrounds, respectful of difference and enlivened by open dialogue, caring and just toward others, and committed to broad participation in achieving the common good.

Board of Trustees
Santa Clara University
Oct. 22, 1993

HISTORICAL PERSPECTIVE

On Jan. 12, 1777, six months after the signing of the Declaration of Independence, a cross was planted at a site in the present city of Santa Clara by a Spanish Franciscan missionary, Tomás de la Peña, to mark the founding of the eighth of California's original 21 missions, Santa Clara de Asís.

Three-quarters of a century elapsed before Santa Clara University, or Santa Clara College as it was known, opened its doors as an institution of higher learning. In the intervening years, however, the mission served as a spiritual center and school for the Indians. Besides religious instruction, the men were taught stockraising, farming, and the building trades; the women, weaving and sewing; the children, reading, music, and religious drama. From 1777 until Mexican government secularization on Feb. 27, 1837, some 9,000 persons were baptized at the mission.

During the early period, the less solidly built mission buildings of the first and second sites were destroyed by the flooding waters of the Rio Guadalupe. The third mission church, constructed of adobe, was completed in 1784 but was seriously damaged by earthquakes in 1812 and 1818. A fourth church, also adobe, was used temporarily from 1819 to 1825. The larger, fifth adobe mission, with its quadrangle patio, was completed and dedicated Aug. 12, 1825. The University's Adobe Lodge Faculty Club is all that remains of the west wing of the quadrangle.

The first site of Mission Santa Clara is marked by a California state historical landmark located near the intersection of Kifer Road and De La Cruz Boulevard. Crosses mark the second site at De La Cruz Boulevard and Martin Street and the third site at Campbell and Franklin streets. The temporary fourth mission church stood between what are now Kenna Hall and the Walsh Administration Building.

During the first three decades of the 19th century, the old mission enjoyed its most fruitful years. In 1827, more than 1,400 Indians lived within sound of the mission's bells. In that year, some 15,000 sheep, 14,500 head of cattle, and abundant crops of wheat, corn, and beans were produced and cared for by the Indians under the guidance of the missionaries.

A combination of factors terminated the decades of prosperity at Santa Clara and the other California missions. The Mexican War of Independence brought turmoil from 1810 to 1821 and resulted in a decrease in Franciscan personnel and donations-in-aid from benefactors. The new Mexican government took possession of the old Jesuit Pious Fund of the Californias that had been the main source of support for the mission. Most of the Indians' lands, cattle, and sheep became the object of spoliation by civil administrators.

In 1827 and again in 1829, governmental decrees ordered exile for all Spaniards who refused allegiance to the new regime. Since most of the mission padres were from Spain, many chose banishment. Some, however, remained until 1833, when Mexican Franciscan replacements arrived from the missionary college of Zacatecas. Among them was Fray Francisco García Diego y Moreno, who was to become the first bishop of the Californias. Although committed to the welfare of the Indians, the padres' resistance to governmental encroachment on the Indians' rights and property had little effect. Full secularization of mission properties was finally imposed at Mission Santa Clara in early 1837. This action ended the effectiveness of the Franciscan missionary endeavor in Alta California.

Within a few years, most of the mission buildings and the Indian lands, cattle, and sheep were seized by civil officials and other claimants. In the early 1840s, foreigners began arriving in Alta California in increasing numbers. Some of the immigrants were Anglo-Americans attracted by the rich agricultural lands of Santa Clara Valley.

Events during 1848 dramatically altered the course of history at Santa Clara. In February, the United States and Mexico signed the Treaty of Guadalupe Hidalgo, which concluded the two-year war in which they had been engaged and ceded California to the United States. That same year gold was discovered in the Sierra Nevada, thus attracting a flood of newcomers into the former Mexican province.

It was in this setting that Santa Clara opened its classroom doors in May 1851. The new bishop of San Francisco, Joseph Sadoc Alemany, asked Jesuits Michael Accolti and John Nobili, formerly Oregon missionaries, to open a college at Mission Santa Clara. During its first academic year, 1851–52, Father Nobili and a handful of Jesuit and lay teachers offered instruction in a variety of subjects to approximately 40 students. A decision made in 1854 by the Jesuit Province of Turin, Italy, to adopt California as a permanent mission field marked a turning point in Santa Clara's history. As a consequence, the Jesuits of Turin provided the college with the faculty and support that it needed to grow. The following year, Santa Clara College received a charter of incorporation from the state of California.* In 1857, the college conferred its first collegiate degree, a Bachelor of Arts diploma, on Thomas I. Bergin. This was the first diploma granted by any institution of higher learning in the state of California. By 1858, new scientific apparatus arrived from Paris, and integrated courses in science as well as in the classics and in commercial subjects were offered.

Slow and steady growth followed, and distinguished graduates became prominent members of California life. It was not until 1912, however, that the Schools of Law and Engineering were founded. In that same year, courses in the humanities and the sciences were expanded, and the college became Santa Clara University. Meeting the demands of urban growth in the Santa Clara Valley, courses in commerce and finance were also expanded in 1926, and the University's School of Business and Administration began. In that same year, the old mission church was destroyed by fire. The present structure, an enlarged replica of the original, was completed in 1928.

From the 1930s through World War II, the University's enrollment was relatively stable. The return of many veterans resulted in an enlarged student body and new resources. In 1947, for the first time in the University's history, enrollment broke the 1,000 mark. From the postwar period to the present, the face of the campus has been changing and expanding. In 1961, the University announced a major change in policy and accepted women as undergraduate students for the first time in its 110-year history. Santa Clara became the first Catholic coeduca-

*THE UNIVERSITY'S LEGAL NAME is *The President and Board of Trustees of Santa Clara College* to which should be added, *A Corporation, located at Santa Clara, California.* For the information of individual, corporation, and foundation donors who wish the tax benefits of their gifts and grants, the University is classified by the Internal Revenue Service as a 501 (c) (3) (ii) tax-exempt organization and it is not classified as a private foundation under section 509(a) of the IRS Code.

tional institution of higher learning in California. Thanks to the generous support of many friends, 23 new buildings have been added to match the growth in enrollments. The Louis B. Mayer Theatre, Leavey Activities Center, and Cowell Health Center were completed in the early 1970s. Additions in the 1980s included a computer center, engineering and computer laboratories, parking facilities, and student housing. The already scenic campus was significantly enhanced in 1989 by rerouting The Alameda, California's oldest north-south highway, around the University. With the new entrance road and landscaping, the reroute unifies the Mission and modern sections of the campus into 104 contiguous acres.

Although the student body has grown rapidly in the past decade, it has been held relatively small: 4,019 undergraduates and 3,706 graduate and law students. Since 1960, educational opportunities at all levels have increased.

As an independent University supported by tuition and gifts, Santa Clara has been able to accomplish change in ways that reflect its traditional concern for the individual student.

Today, Santa Clara University, the first institution to offer classes in higher learning on the West Coast, continues its mission heritage of service by helping its students equip themselves with advanced knowledge and humanistic values. Academic excellence in a well-balanced human being is the University's goal.

CAMPUS LOCATION

Santa Clara University is 46 miles from San Francisco, near the southern tip of the San Francisco Bay, in an area rich in opportunities for learning. The campus is situated in the midst of one of the nation's great concentrations of high-technology industry (Silicon Valley) and professional and scientific activity. Many nearby firms and social agencies are world leaders in the search for solutions to humanity's most critical problems. The cultural and entertainment centers of San Francisco, Berkeley, Oakland, and Marin County are within one-hour's travel by bus, train, or car. In the opposite direction, the Pacific beaches of Santa Cruz are about 30 minutes away; the world-famous Monterey Peninsula and Carmel are two hours away. The University is accessible by major airlines via San Jose International Airport, which is three miles from campus, and via San Francisco and Oakland International airports.

Santa Clara has a moderate Mediterranean climate. During a 67-year period, the average maximum temperature was 71.4 degrees Fahrenheit and the average minimum, 41.6 degrees. The sun shines an average of 293 days per year, and the average annual rainfall is about 15 inches.

2

Admissions

The School of Engineering offers the following graduate programs:

1. Master of Science in Applied Mathematics, Civil Engineering, Computer Engineering, Electrical Engineering, Engineering, Engineering Management, and Mechanical Engineering
2. Engineer's degree in Electrical Engineering and Mechanical Engineering
3. Doctor of Philosophy in Computer Engineering, Electrical Engineering, and Mechanical Engineering

In addition, the School offers certificate programs that are described in Section 4 (Pages 32–36).

Application for admission to graduate programs should be made to the dean of the School of Engineering on the form available from that office. Two separate, original, and official transcripts from each college or university attended, together with official evidence of degrees conferred, must be sent directly to the Office of the Dean by the issuing institution, and received by the date specified on the application form. Material received later than this date may delay admission.

The minimum requirements for admission are as follows:

1. A bachelor's degree in engineering from an Accreditation Board for Engineering and Technology (ABET)-accredited four-year program; or a bachelor's degree in computer science, mathematics, or one of the physical sciences from a four-year college or a university substantially equivalent to that of Santa Clara University. (The applicant must have completed one and one-half years of calculus.)
2. An overall GPA of 2.75 (based on a 4.0 maximum)—individual programs may require a higher average. Consult with the specific department.
3. General test of the Graduate Record Examination (GRE).

Note that specific programs have additional requirements as listed in Section 3 (Pages 17–31).

Admission to graduate study is based on records of undergraduate work. If the undergraduate work was done in a country where English is not the official language, a student is required to submit, in addition to the above requirements, test scores on the Test of English as a Foreign Language (TOEFL). International students requesting Immigration Form I-20 must submit a financial statement showing adequate funds for tuition, fees, and living expenses for the entire program. The University strongly encourages review courses in English (offered as a service at no tuition) and appropriate undergraduate courses, not for graduate credit,

when it finds that an individual's progress is suffering because of a language difficulty.

Accepted international students will receive a letter of acceptance that they must show to the U.S. consular officer to whom they apply for a student visa. They also must enroll in at least 8 units per quarter.

The School of Engineering reserves the right to deny admission if the applicant's previous program does not furnish an adequate foundation for advanced academic study.

3

Academic Regulations

GENERAL INFORMATION

Classes

Most classes are taught between 7 and 9 a.m., Monday through Friday; 2-unit courses meet one day per week, and 4-unit courses meet two days per week. A few courses meet in the evening.

Program of Study

During the first quarter of enrollment, a student whose objective is a graduate degree must obtain a faculty adviser through the department's office. An adviser-approved program of study, including any transfer units, must be submitted to the Graduate Admissions Office before the end of the first quarter of enrollment. (Two separate, original, and official transcripts must be on file before any review will be made.)

Variations from the approved program of study may be made only with the written approval of the adviser and the filing of the proper forms.

Units earned in a nonmatriculated status may be applied toward graduation upon approval of the academic adviser.

Nongraded Courses

Courses such as seminars, co-op, etc., are limited to a total of 5 units (approved by the adviser).

Petition for Graduation

The student is responsible for filing a petition for graduation, available from the Office of the Dean, during the quarter prior to the last quarter of study but not later than the "last day to petition for graduate degrees" as indicated in the Academic Calendar (Pages 6–8). If the petition is submitted late, the date of graduation will be postponed for at least one quarter; graduation dates are not retroactive.

Incomplete Grades

A student's work may be reported incomplete if due to illness or other serious circumstance some essential portion of the course work remains unfinished after the final examination or if the thesis has not been completed. An incomplete

(I) becomes a failure (F) unless the unfinished work is completed to the satisfaction of the instructor and proper notice is filed with the registrar within four weeks from the beginning of the next scheduled term, not including summer session, whether or not the student is registered during that term. Makeup work must be in the hands of the concerned faculty member no later than the end of the third week so that the professor can meet the four-week submission deadline.

Cooperative Education Option

The Cooperative Education option integrates classroom work with practical industrial experience. It provides alternate or parallel periods of college education with periods of practical training in industry. The industrial training is related to the field of study in which the student is engaged and often is diversified to afford a wide range of experience. The objective of cooperative education is to provide students with the opportunity, through this interaction of study and work experience, to enhance their academic knowledge, to further their personal work experience, and to learn about working with people.

To qualify for this study option, students must complete at least 12 quarter units at Santa Clara University. Interested students should contact the Cooperative Education Office in the Career Services Office early in their academic program.

Participating students pay tuition for 1 or 2 units and an administrative fee of $125 per unit.

MASTER OF SCIENCE PROGRAM

The master's degree will be granted to degree candidates who complete a program of studies approved by the major department. It must include no less than 45 quarter hours, of which 9 may be earned by completing a thesis. In addition, a 3.0 GPA (B average) must be earned in all course work taken at Santa Clara. Residence requirements of the University are met by completing 36 quarter hours of the graduate program at Santa Clara. A maximum of 9 quarter units (6 semester units) may be transferred from other accredited institutions at the discretion of the student's adviser. All units applied toward the degree, including those transferred from other institutions, must be earned within a six-year period.

Students have the option to write a thesis as part of their master's degree. They are responsible for obtaining an adviser for thesis work. The maximum number of units awarded for the master's thesis is 9 units.

Note that the number of engineering management courses accepted for other degrees in the graduate engineering program is restricted to 6 units in computer engineering, electrical engineering, and mechanical engineering, and to 10 units in the Master of Science in Engineering Program.

REQUIREMENTS FOR MASTER OF SCIENCE

Applied Mathematics (AMTH)

The Applied Mathematics Program is open to those students who have earned a B.S. degree in engineering, science, or mathematics, provided the student has completed a program in undergraduate mathematics that parallels the program of the mathematics major at Santa Clara University. The core program at Santa Clara includes calculus and differential equations, abstract algebra, linear algebra, advanced calculus and/or real analysis, and a minimum of five upper-division courses chosen from the areas of analysis, complex variables, partial differential equations, numerical analysis, logic, probability, or statistics.

Courses for the master's degree must include no fewer than 35 quarter units in applied mathematics with a minimum of 12 quarter units in 300-level courses. Students whose undergraduate degree is not in mathematics must take the entire 45 quarter units in applied mathematics courses. Students with an undergraduate degree in mathematics may take up to 10 quarter units in certain approved areas in engineering.

Civil Engineering (CENG)

Students in the Civil Engineering Graduate Program may emphasize in the area of *structural engineering*. To qualify for the degree of Master of Science in Civil Engineering, students must complete a minimum of 45 quarter units, including seven core courses and elective courses in the Applied Mathematics and Civil Engineering departments. All core and elective courses are 2 quarter units unless indicated otherwise.

Core courses:

CENG 211 (Advanced Strength of Materials) (4)
CENG 222 (Advanced Structural Analysis) (4)
CENG 234 (Advanced Steel Structures)
CENG 235 (Advanced Concrete Structures) (4)
CENG 238 (Earthquake Engineering I)
AMTH 220 (Numerical Analysis I)
AMTH 245 (Linear Algebra I)

Electives may be taken from the following lists of civil engineering and applied mathematics courses. Students must take at least one applied mathematics course sequence.

1. Civil Engineering Elective Courses

CENG 205 (Finite Element Methods I)
CENG 206 (Finite Element Methods II)
CENG 207 (Finite Element Methods III)
CENG 209 (Thin Plates and Shells) (4)
CENG 210 (Behavior of Metal Structures)
CENG 212 (Variational Methods in Mechanics)

CENG 214 (Theory of Elasticity) (4)
CENG 215 (Advanced Construction Materials)
CENG 216 (Theory of Plasticity)
CENG 217 (Advanced Theory of Shells)
CENG 218 (Structural Dynamics) (4)
CENG 219 (Advanced Dynamics)
CENG 221 (Stability of Structures) (4)
CENG 226 (Plastic Theory of Structures)
CENG 227 (Experimental Stress Analysis)
CENG 228 (Fracture Mechanics of Solids)
CENG 229 (Mechanical Properties of Materials)
CENG 230 (Random Vibrations)
CENG 233 (Timber Engineering)
CENG 237 (Shock Waves in Solids)
CENG 239 (Earthquake Engineering II)
CENG 240 (Composite Structures) (4)
CENG 241 (Reliability of Engineering Systems)
CENG 242 (Soil-Structure Interaction)
CENG 244 (Nonlinear Elasticity)
CENG 246 (Masonry Engineering)
CENG 247 (Cold-Formed Steel and Aluminum Design)
CENG 248 (Plate Girder and Composite Design)
CENG 297 (Thesis Research) (1–9 units)
CENG 299 (Independent Study) (1–6 units)

2. Applied Mathematics Elective Courses

AMTH 214 (Engineering Statistics I)
AMTH 217 (Design of Scientific Experiments)
AMTH 221 (Numerical Analysis II)
AMTH 230 (Applied Mathematics I)
AMTH 231 (Applied Mathematics II)
AMTH 245 (Linear Algebra I)
AMTH 246 (Linear Algebra II)

A maximum of three electives, other than those indicated in 1 and 2 above, may be taken in the Mechanical Engineering, Computer Engineering, and Engineering Management departments with the permission of the student's adviser.

Computer Engineering (COEN)

All students admitted to the program are expected already to have competence in the fundamental subjects listed below, as required within an accredited program for a B.S. in Computer Engineering or Computer Science. An applicant without such background may still be admitted provided the deficiencies are corrected by course work that is in addition to the normal degree requirements and that must be completed with a B average within the first year of graduate studies. The subjects and courses that may be used to correct the deficiencies include:

1. Logic design: COEN 21C (Introduction to Logic Design)
2. Advanced logic design: COEN 120A (Introduction to Microprocessors I) or COEN 127C (Sequential Logic Design)
3. Data structures: COEN 7C (Introduction to Data Structures)
4. Computer organization and assembly language: COEN 11C (Introduction to Digital Hardware)
5. Discrete math or modern algebra: AMTH 240 (Modern Algebra I)
6. Probability: AMTH 210 (Probability I) or Statistics: AMTH 214 (Engineering Statistics I)
7. One of the following:
   a. Differential equations: AMTH 106 (Differential Equations)
   b. Numerical analysis: AMTH 220 and 221 (Numerical Analysis I and II)
   c. Linear algebra: AMTH 245 and 246 (Linear Algebra I and II)

The above are considered undergraduate-level courses and cannot be used to satisfy the requirements for the M.S. in Computer Engineering.

Students must file a program of studies during their first term of enrollment at Santa Clara. The program of studies requires a minimum of 45 units and must include:

1. One two-course sequence in applied math (4 units)
2. All of the following (12 units):
   a. COEN 210 (Computer Architecture)
   b. COEN 251 (Data Structures & Algorithms)
   c. COEN 283 (Operating Systems)
3. One of the following (3 or 4 units, depending on option selected, a–e):
   a. COEN 209 (Switching Theory)
   b. COEN 257 (Formal Languages and Introduction to Compiler Construction)
   c. COEN 260 (Truth, Deduction, and Computation)
   d. COEN 270 (Automata and Computability Theory)
   e. Two courses in applied math, selected with approval of adviser, from: AMTH 211, 225, 226, 241, 242, 280, 281, 305, 306, 308, 309, 315, 316, 332, 334, 335, 340, 341, 346, 347, 358, 362, 363, 370, 371, 380, 381
4. 20 units of other computer engineering courses (COEN 200–399); at least 8 units of these selected from COEN 300–399 or COEN 497–499
5. Additional units of graduate electives to bring the total program to 45 units

IMPORTANT: In general, no credit will be allowed for courses that duplicate prior course work, including courses listed above as degree requirements. Students should arrange adjustment of these requirements with their academic adviser when they file their program of studies.

Note: With the prior written consent of the adviser, students may take a maximum of 12 units of course work for graduate credit from selected senior-level undergraduate courses.

Electrical Engineering (ELEN)

Students must file a program of studies during their first term of enrollment at Santa Clara. The program of studies must contain a minimum of 25 electrical engineering units and must include the following:

1. One graduate course in electromagnetic fields (ELEN 701, 702, 703, or 704)
2. Two graduate courses in modern networks (ELEN 211 and ELEN 212, 213, or 214)
3. One graduate course in control systems (ELEN 236)
4. One graduate course in electronics (ELEN 251–279, 371–389)
5. One graduate course in digital systems (ELEN 500)
6. Four applied mathematics courses, including the AMTH 245–246 sequence if linear algebra has not been completed previously
7. Such additional courses in the student's emphasis area and in other areas as developed with the adviser and approved as part of the student's total program (minimum of 45 hours)

These requirements may be adjusted by the adviser based on the student's previous graduate work. Alterations in the approved program, not relating to the above departmental requirements, may be requested at any time by a petition initiated by the student and approved by the adviser. The program may include up to 6 engineering management units, with the adviser's agreement.

Analog Electronics (Leach)

1. ELEN 251, 252, 253, 254, 255, 256
2. Two courses from ELEN 217, 218, 219, 220, 267, 381, 382, 485, 486

Circuits and Systems (Siljak)

1. Circuits and systems core (8 units): ELEN 211, 212, 214, 229
2. General ELEN core (14 units): ELEN 236, 251 or 252, 701; AMTH 245, 246, 346, 347
3. Electives (select any two *groups* from the following for a total of 8 units): ELEN 215 and 216, 217 and 220, 218 and 219
4. Recommended courses (select *groups* of courses from the following for a total of at least 15 units): AMTH 370 and 371; ELEN 252 and 253; 264, 265, and 266; 371 and 372; 381 and 382; 387 and 388; 510, 511, and COEN 251; COEN 283 and 285; ELEN 213, 229, 297, 299

Communications (Healy)

1. Data communications and computer networks: AMTH 210, 211, 245; ELEN 241, 242, 243; COEN 233; one course from COEN 330 or 332; three courses from ELEN 233, 234, 244, 248, 345, 346, 347; COEN 251, 283

2. Communications theory: AMTH 210, 211, 362; ELEN 241, 242, 243; three courses from ELEN 244, 245, 246, 247, 248, 345, 346, 347, 441, 442; two courses from AMTH 358, 363 and ELEN 233, 234, 257, 258, 335, 706, 707, 708, 709, 711, 712, 713, 715, 716, 717, 718, 721, 725, 726, 727

Control Systems (Siljak)

1. Control systems core:
   a. AMTH 245, 246 or 315, 316; ELEN 232, 236, 330
   b. At least four courses from ELEN 231, 233, 235, 237–239, 331–339
2. Specialty areas:
   a. Control and digital signal processing: ELEN 233, 235; four additional courses from ELEN 234, 331, 333–336
   b. Robotics and automation: ELEN 329, 337–339; MECH 352–353
   c. Intelligent control: ELEN 328 and 329

Digital Signal Processing (Wood, Ogunfunmi)

1. Digital signal processing core:
   a. AMTH 245, 246 or 315, 316; 210, 211 or 362, 363
   b. ELEN 233, 234
   c. At least four courses numbered ELEN 330–489 or 640–649
2. Specialty areas:
   a. Digital signal processing and communications: ELEN 233, 234, 235, 241, 242, 243
   b. Digital signal processing and architecture: ELEN 233, 234, 235, and three from 510, 511, COEN 312, 313, 322, 323
   c. Digital signal processing and image processing: ELEN 233, 234, 235, 640, 641; and 433, 642, or 644
   d. Digital signal processing and control: ELEN 233, 234, 237, 333, 335, 336
   e. Adaptive signal processing: ELEN 233, 234, 235, 431, 432, 435

Digital Systems Design (Mourad, Ogunfunmi, Wood)

1. AMTH 245, 246 or 315, 316; 210, 211 or 362, 363
2. ELEN 387, 388, 473, 475, 476, 600, 609
3. One additional course from ELEN 330–489

Electromagnetics and Microwaves (Yarbrough)

Specialty areas:

1. Microwave circuits: ELEN 702, 705, 707, 708, 711, 712, 726
2. Microwave devices: ELEN 261, 264, 265, 702, 707, 708, 711
3. Electromagnetics and antennas: ELEN 702, 703, 708, 715, 716, 717; AMTH 230, 231

Information Storage Technology (Hoagland, Yarbrough)

1. ELEN 460, 461
2. Four additional courses from ELEN 450–479
3. Additional electrical engineering courses (ELEN 211–229, 231–249, 251–289, 330–489, 701–729) to bring the total electrical engineering units to a minimum of 23

Microelectronics (Rahman, Yang)

1. Microelectronics core: ELEN 261, 264, 265, 266, 274, 275
2. Special focus areas
   a. Materials, devices, and processing electives: ELEN 251, 276, 373, 374, 375, 377, 378, 380, 384, 385, 386
   b. Microelectronics manufacturing science and technology electives: ELEN 337, 338, 339, 385, 387, 388, 389; AMTH 214, 215, 216, 218; EMGT 270, 271, 272, 316, 327; DISC 201, 208, 209, 294, 297 (see *Leavey School of Business and Administration Graduate Programs* bulletin)

Power Systems (Peterson)

1. Electric utility engineering
   a. Required: ELEN 281–285; AMTH 245–246; two courses from AMTH 220, 221, 230, 231, 298, 299; some additional courses from ELEN 286–289, 480–489
   b. Electives: up to 8 units in engineering management; remainder from ELEN and MECH courses
2. Industrial power engineering
   a. Required: ELEN 281–283, 285, 481–483, 485–488; AMTH 245–246; two courses from AMTH 210–211, 214–215, 220–221, 230–231; some additional courses from ELEN 280– 289, 480–489
   b. Electives: up to 8 engineering management units; remainder from ELEN and MECH courses

VLSI Design and Test (Mourad)

1. One of the two series: AMTH 216–217 or AMTH 280–281
2. VLSI core: ELEN 266, 371, 372, 387, 388
3. Specialty areas: at least three from ELEN 389, 601, 603, 606, 608, 610, COEN 388

Engineering

This program accommodates those whose goals do not fall within the patterns of the designated degree programs (e.g., a program that combines engineering, applied mathematics, computer engineering, and engineering management). The program must be approved by an adviser and filed as a program of studies.

Engineering Management (EMGT)

The Engineering Management degree focuses on how we work—the management of technical activities through which the manager integrates physical and human resources. Technical managers ensure that personal and organizational objectives are realized by coupling task and process in the achievement of objectives primarily in the areas of research, development, design, operations, testing, marketing, and field service. Engineering management course work encompasses these activities and the ways in which they interface with other activities within organizations.

Unlike more general programs in management or in business administration, this program accommodates the unique formal education of engineers and is designed specifically for those who expect to manage in technical settings.

Admissions Admission to the Engineering Management Program is open only to those who hold an undergraduate degree or graduate degree in engineering or computer science. The undergraduate program must be a four-year engineering program substantially equivalent to Santa Clara's. In addition, students must have two years of full-time work experience after receiving their bachelor's degree.

Requirements Forty-five quarter units are required for the master's degree at Santa Clara. For the Engineering Management degree, 20 of these units must be in civil, electrical, computer, or mechanical engineering; or applied mathematics; or a combination of all of these. A minimum of 20 units must be undertaken in the engineering management sequence. The remaining 5 units may be taken in either management or a technical area. Although 9 units may be transferred from the Leavey School of Business or another graduate program, in no case may the minimum units in a stem be fewer than 16. Note that the number of engineering management courses accepted for other degrees in the graduate engineering program is restricted to 6 units in the Computer Engineering, Electrical Engineering, and Mechanical Engineering programs, and to 10 units in the M.S. in Engineering degree program.

The program of studies for Engineering Management degree candidates must be submitted to the chair of the Engineering Management Department during the first term of enrollment to ensure that all courses undertaken are applicable to the degree. Engineering Management 250 is the required introductory course. In addition, 252, 301, and 330 are required of all Engineering Management degree candidates.

Graduate seminars in other departments—ELEN 200 or COEN 400 or MECH 297—are not applicable to an Engineering Management degree program.

In addition to the overall 3.0 GPA graduation requirement, Engineering Management degree candidates must earn a 3.0 GPA in those courses applied to their technical stem and a 3.0 GPA in their engineering management course stem. All courses in which a student is enrolled at Santa Clara are included in these calculations.

Mechanical Engineering (MECH)

All students in the Mechanical Engineering Program are required to take MECH 202 at the beginning of their program of studies and must complete at least two sequences of two courses in applied mathematics.

Students must select one of four options and develop a program of studies with an adviser.

All full-time students, and all students in the manufacturing option, are required to complete a thesis for their degree.

Thermofluids (Haddad, Ma, Saad)

The program of studies for the *thermofluids option* must include the following courses:

MECH 225 and 226 (Gas Dynamics I and II)
MECH 266 (Fundamentals of Fluid Mechanics)
MECH 270 and 271 (Viscous Flow I and II)

and any five of the following courses:

MECH 228 (Equilibrium Thermodynamics)
MECH 230 (Statistical Thermodynamics)
MECH 236 and 237 (Conduction Heat Transfer I and II)
MECH 238 (Convective Heat and Mass Transfer I)
MECH 240 (Radiation Heat Transfer I)
MECH 267 (Inviscid Flow)

Dynamics and Controls (Ardema, Menon)

The program of studies for the *dynamics and control option* must include the following courses:

MECH 203 and 204 (Analytical Dynamics I and II) or MECH 214, 215, and 216 (Advanced Dynamics I, II, and III)
MECH 205 (Introduction to Vibrations) or MECH 141 (Introduction to Linear Systems)
MECH 217 (Introduction to Control) and MECH 218 (Guidance and Control I), or MECH 142 (Control Systems Analysis and Design)
MECH 266 (Fundamentals of Fluid Mechanics)

and at least four of the following sequences of courses:

MECH 203 and 204 (Analytical Dynamics I and II)
MECH 210 and 211 (Nonlinear Oscillations I and II)
MECH 214, 215, and 216 (Advanced Dynamics I, II, and III)
MECH 301 and 302 (Noise and Vibration Control and Monitoring I & II)
MECH 315 and 316 (Advanced Digital Control Systems I and II)
MECH 323 and 324 (Modern Control System Design I and II)
MECH 337, 338, and 339 (Robotics I, II, and III)

MECH 429 and 430 (Optimization of Dynamic Systems I and II)
MECH 431 (Aircraft Flight Dynamics and Performance) and 432 (Rocket and Spacecraft Dynamics)

Computer-Aided Design (Hight, Sanchez)

The program of studies for the *computer-aided design option* must include the following courses:

CENG 205, 206, and 207 (Finite Element Methods I, II, and III)
MECH 275 (Design for Competitiveness)
MECH 284 (Computer-Aided Engineering)
MECH 325 and 326 (Computational Geometry for Computer-Aided Design and Manufacture I and II)
MECH 415 (Optimization in Mechanical Design)

The following are other suggested sequences for this option:

MECH 207, 208, and 209 (System Design I, II, and III)
MECH 220 and 221 (Electromechanical Devices in Computer Peripherals I and II)
MECH 273 and 274 (Designing with Plastic Materials and Processing Plastic Materials)
MECH 281 and 282 (Fracture Mechanics and Fatigue I and II)
MECH 330, 331, and 332 (Structure and Properties of Modern Materials I, II, and III)

Manufacturing (Hornberger)

The program of studies for the *manufacturing option* must include the following courses:

MECH 207, 208, and 209 (System Design I, II, and III)
MECH 275 (Design for Competitiveness)
MECH 299 (Thesis)
MECH 330, 331, and 332 (Structure and Properties of Modern Materials I, II, and III)

and at least six of the following courses:

MECH 273 and 274 (Designing with Plastic Materials and Processing Plastic Materials)
MECH 340 (Introduction to Direct Access Storage Devices) and 341 (Direct Access Storage Devices)
MECH 350 and 351 (Composite Materials I and II)
MECH 352 and 353 (Automation and Computer-Integrated Manufacturing I and II)
ELEN 274 and 275 (Integrated Circuit Fabrication Processes I and II)
ELEN 385 and 386 (VLSI Fabrication Technology I and II)

Students in the *manufacturing* option may take up to 10 units of approved graduate courses in the Engineering Management Department or the Leavey School of Business and Administration.

These requirements may be adjusted on the basis of the student's previous work; however, any adjustment must be approved by the departmental adviser.

ENGINEER'S DEGREE PROGRAM

The program leading to the Engineer's degree is particularly designed for the education of the practicing engineer. It is offered in the Electrical Engineering and Mechanical Engineering departments. The degree is granted on completion of an approved academic program and a record of acceptable technical achievement in the candidate's field of engineering. The academic program consists of a minimum of 45 quarter units beyond the master's degree. Courses are selected to advance competence in specific areas relating to the engineering professional's work. Evidence of technical achievement must include a paper principally written by the candidate and accepted for publication by a recognized engineering journal prior to the granting of the degree. A letter from the journal accepting the paper must be submitted to the Office of the Dean, School of Engineering. In certain cases, the department may accept publication in the proceedings of an appropriate conference.

Admission to the program will generally be granted to those students who demonstrate superior ability in meeting the requirements for their master's degree. Normally, the master's degree is earned in the same field as that in which the Engineer's degree is sought. Students who have earned a master's degree from Santa Clara University must file a new application (meeting deadlines) to continue work toward the Engineer's degree. A program of studies for the Engineer's degree should be developed with the assistance of an adviser and submitted during the first term of enrollment.

In the field of electrical engineering, courses the Department of Electrical Engineering considers at the introductory Master of Science level (e.g., ELEN 210, 211, 212, 230, 231, 236, 241, 250, 251; AMTH 210, 211, 220, 221, 230, 231, 235, 236, 240, 245, 246) are not generally acceptable in an Engineer's degree program of studies. However, with the approval of the adviser, the student may include up to three of these courses in an Engineer's degree program. The department also requires that at least 15 units of the program of studies be in topics other than the student's major field of concentration. Candidates admitted to the Electrical Engineering Program who have M.S. degrees other than in Electrical Engineering must include in their graduate programs (M.S. and Engineer's degree combined) a total of at least 45 units of graduate-level electrical engineering course work exclusive of computer software courses.

Students should consult the departments for other degree requirements.

DOCTOR OF PHILOSOPHY PROGRAM

The Doctor of Philosophy degree is conferred by the School of Engineering primarily in recognition of a new contribution to knowledge in the field, demonstrated competence in the subject, and the ability to investigate engineering problems independently.

The work for the degree consists of a program of advanced studies in engineering, mathematics, and related physical science, engineering research, and a thesis based on that research. The student's work is directed by the degree-conferring department, subject to the general supervision of the School of Engineering. The School grants the Ph.D. in Computer Engineering, Electrical Engineering, and Mechanical Engineering.

Application Procedure

An academic achievement of the master's level in a related area of engineering or science is required of all applicants. Applicants holding a bachelor's degree should first apply for study toward a master's degree and indicate their intention to continue studying for the doctoral degree.

All students must take the General Aptitude Test of the Graduate Record Examination (GRE) and must request that the results be sent to the dean, School of Engineering. All correspondence regarding the GRE should be addressed to Graduate Record Examinations, Educational Testing Services, P.O. Box 6000, Princeton, NJ 08541-6000.

Applicants must also file

1. an application for admission to the Ph.D. program (application forms are available at the Office of the Dean, School of Engineering);
2. three letters of recommendation; and
3. a statement of research interests and objectives, and transcripts from all colleges and universities attended.

Students become Ph.D. students when they complete the requirements listed above and are accepted to the program.

Preliminary Examination

The preliminary examination shall be written and/or oral, as determined by the major department, and shall include subject matter deemed by the major department to represent sufficient preparation in depth and breadth for advanced study in the major.

Students currently studying at Santa Clara University for a master's degree who are accepted for the Ph.D. program and who are at an advanced stage of the M.S. program may, with the approval of their academic adviser, take the preliminary examination before completing the M.S. degree requirements.

Students who complete the M.S. degree requirements at Santa Clara University before being accepted for the Ph.D. program should take the preliminary ex-

amination as soon as possible but, in any case, not more than one and one-half years after beginning the program.

Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be repeated only once, and then only at the discretion of the thesis adviser.

General Requirements

Thesis Adviser It is the student's responsibility to obtain consent from a full-time faculty member in the student's major department to serve as his/her prospective thesis adviser.

It is strongly recommended that Ph.D. students find a thesis adviser before taking the preliminary examination. After passing the preliminary examination, Ph.D. students should have a thesis adviser before the beginning of the next quarter following the preliminary examination. Students currently pursuing a master's degree at the time of their preliminary examination should have a thesis adviser as soon as possible after being accepted as a Ph.D. student.

The student and the thesis adviser jointly develop a complete program of studies for research in a particular area. The complete program of studies (and any subsequent changes) must be filed with the Office of the Dean of Engineering and approved by the student's Doctoral Committee. Until this approval is obtained, there is no guarantee that courses taken will be acceptable toward the Ph.D. course requirements.

Doctoral Committee On the student's request, the thesis adviser will form a Doctoral Committee. The committee will consist of at least five members, including the thesis adviser and at least two members from the major department. The committee must also include at least one member from outside the major department, preferably from outside the School of Engineering. The Doctoral Committee will review the proposed program of studies and determine any further changes that may be required prior to approving the program.

Residence The doctoral degree is granted on the basis of achievement, rather than on the accumulation of units of credit. However, the candidate is expected to complete a minimum of 90 quarter units of graduate credit beyond the master's degree. The program, as approved by the Doctoral Committee, typically includes 45 quarter units of course work and 45 quarter units of thesis research.

A minimum of four consecutive quarters of full-time study must be undertaken at the University for the doctorate; spring and fall quarters are considered consecutive. The residency time shall normally be any period between passing the preliminary examination and completion of the thesis. For this requirement, full-time study is interpreted as a minimum registration of 8 units per quarter during the academic year and 4 units during summer session. Any variation from this requirement must be approved by the Doctoral Committee.

Comprehensive Examinations and Admission to Candidacy Upon completion of the formal course work approved by the Doctoral Committee, the student shall present him-/herself for comprehensive oral examinations on the subject of

his/her course work. The student should make arrangements for the comprehensive examinations through the Doctoral Committee. A student who passes the comprehensive examinations is considered a degree candidate.

The comprehensive examinations normally must be completed within four years from the time the student is admitted to the doctoral program. Comprehensive examinations may be repeated once, in whole or in part, at the discretion of the Doctoral Committee.

Thesis Research and Defense The period following the comprehensive examinations is devoted to research for the thesis, although such research may begin before the examinations are complete. After successfully completing the comprehensive examinations, the student must complete his/her research and pass an oral examination on the research and thesis, conducted by the Doctoral Committee and whomever they appoint as examiners. The thesis must be made available to all examiners one month prior to the examination. The oral examination shall consist of a presentation of the results of the thesis and the defense. This examination is open to all faculty members of Santa Clara University, but only members of the Doctoral Committee have a vote.

Thesis and Publication At least one month before the degree is to be conferred, the candidate must submit to the Office of the Dean of Engineering two copies of the final version of the thesis describing the research in its entirety. The thesis will not be considered as accepted until approved by the Doctoral Committee and one or more refereed articles based on it are accepted for publication in a professional or scientific journal approved by the Doctoral Committee.

All doctoral theses must also be reproduced on microfilm by University Microfilms International, which keeps on deposit the master microfilm copy and responds to requests for copies by individuals and libraries.

Time Limit for Completing Degrees All requirements for the doctoral degree must be completed within eight years following acceptance for the Ph.D. program. Extensions will be allowed only in unusual circumstances and must be approved in writing by the Committee on Graduate Programs and the dean of the School of Engineering.

Additional Graduation Requirements

The requirements for the doctoral degree in the School of Engineering establish the structure in which the degree may be earned. Upon written approval of the vice president for academic affairs, the dean of the School of Engineering, the Doctoral Committee, and the chair of the major department, other degree requirements may be established. The University reserves the right to evaluate the undertakings and the accomplishments of the degree candidate in total and award or withhold the degree as a result of its deliberations.

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Certificate Programs

GENERAL INFORMATION

Certificate programs are designed to provide intensive background in a narrow area at the graduate level. At roughly one-third of the units of a master's degree program, the certificate is designed to be completed in a much shorter period of time. These certificate programs are appropriate for students working in industry who wish to update their skills or for those interested in changing their career path.

Admission

To be accepted to a certificate program, the applicant must have a bachelor's degree with a GPA of at least 2.75. For other admission requirements, consult the section on the specific certificate.

Application Procedure

Application for admission to a certificate program should be made to the dean, School of Engineering, on an application form available from that office. Two official copies of a transcript with evidence of a bachelor's degree must be sent directly to the Office of the Dean and received by the deadline specified on the application form. Material received later than this date may delay admission.

Grade Requirements

Students must receive a minimum grade of C in each course and an overall GPA of 3.0 or better to earn a certificate of completion.

Continuation for a Master's Degree

All Santa Clara University courses applied to the completion of a certificate program earn graduate credit that may also be applied toward a graduate degree. Students who wish to continue for such a degree must submit a separate application and satisfy all normal admission requirements. The general GRE test requirement for graduate admission to the master's degree will be waived for students who complete a certificate program with a GPA of 3.5 or better.

ACADEMIC REQUIREMENTS

Advanced Studies in Software Engineering

This certificate program places an emphasis on methodologies used during the development of large, complex software. The program is appropriate for anyone who is developing new software, maintaining existing software, or who is the technical head of a software development project. It is especially relevant for those who have had little or no experience with recent advances in software technology, such as object-oriented design or graphical user interfaces.

In addition to the general requirements, students must have two years of industrial experience in software development and prior course work in data structures and algorithms (e.g., COEN 251) and software engineering (e.g., COEN 285).

Required Courses (12 units)

COEN 286 (Software Quality Assurance & Testing) (2)
COEN 287 (Software Development Process Management) (2)
COEN 385 (Formal Methods in Software Engineering) (2)
COEN 386 (Software Architectures) (2)
COEN 387 (Software Analysis, Maintenance, and Reverse Engineering) (2)
COEN 481 (Software Engineering Project) (2)

Elective Courses (Select any 4 units)

COEN 261 (Structure and Interpretation of Computer Programs) (2)
COEN 276 (Software Tools Design) (4)
COEN 277 (Graphical User Interface Design and Programming) (2)
COEN 388 (Principles of Computer-Aided Engineering Design) (2)
COEN 396 (Advanced Topics: Object-Oriented Analysis and Design) (2)
COEN 396 (Advanced Topics: Object-Oriented Programming) (2)
EMGT 332 (Software Engineering Economics) (2)
EMGT 339 (Quality Issues in Managing Software) (2)
EMGT 341 (Software Project Issues) (2)

Advanced Studies in High-Performance Computing

This certificate program provides proficiency in high-performance architectures, particularly parallel computing and the software methodologies used with such architectures. The program is appropriate for both computer architects and software developers dealing with large scientific and data-processing applications. In addition to the general admission requirements, students are expected to have completed an introductory-level course in computer architecture and operating systems; students without this background may be admitted but will be required to take additional course work.

Required Courses (6 units)

COEN 312 (Parallel Computation Systems I) (2)
COEN 314 (Parallel Computation Systems II) (2)
COEN 319 (Advanced Parallel Programming) (2)

Elective Courses (Select any 10 units)

COEN 233 (Computer Networks) (4)
COEN 307 (Digital Computer Arithmetic) (2)
COEN 309 (Fault-Tolerant Digital Systems) (2)
COEN 311 (Comparative Computer Architecture) (2)
COEN 313 (Advanced Computer Architecture) (2)
COEN 315 (Computer Performance Evaluation) (2)
COEN 316 (Application-Specific Array Processors) (2)
COEN 322 (Advanced Microprocessor Architecture) (2)
COEN 330 (Design and Analysis of Computer Networks) (2)
COEN 332 (Local Area Networks) (2)
COEN 338 (High-Performance Data Compression) (4)
COEN 358 (Introduction to Parallelizing Compilers) (4)
COEN 384 (Advanced Operating Systems) (2)

ASIC Design and Test

This certificate program has a dual purpose: (a) to strengthen fundamental knowledge of the design process that helps the designer adapt to future innovations in technology; and (b) to introduce the designer to state-of-the-art tools and techniques. The program consists of the eight courses listed below. Any change in the requirements must be approved by the academic adviser.

Required Courses (16 units)

ELEN 387 (VLSI Design I) (2)
ELEN 388 (VLSI Design II) (2)
ELEN 500 (Advanced Digital Design) (2)
ELEN 603 (Logic Design Using HDL) (2)
ELEN 601 (Logic Synthesis) (2)
ELEN 606 (Integrated Circuits Testing) (2)
ELEN 608 (Design for Testability) (2)
ELEN 697 (Research Seminar in Digital Systems) (2)

Manufacturing

This program provides the background to understand and utilize modern computer-aided manufacturing technology.

Required Courses (10 units)

MECH 284 (Computer-Aided Design) (2)
MECH 293 (Special Topics in Manufacturing and Materials) (2)
AMTH 214 (Engineering Statistics I) (2)
AMTH 215 (Engineering Statistics II) (2)
AMTH 218 (Process Troubleshooting and Control) (2)
AMTH 219 (Analysis of Scientific Experiments) (2)

Elective Courses (Select any 4 units)

MECH 273 (Designing with Plastic Materials) (2)
MECH 274 (Processing Plastic Materials) (2)
MECH 275 (Design for Competitiveness) (2)
MECH 352 (Automation and Computer-Integrated Manufacturing I) (2)
MECH 353 (Automation and Computer-Integrated Manufacturing II) (2)

Mechanical Design Analysis

This certificate program covers tools used in the analysis of design concepts, including finite element analysis, optimization, and computational geometry.

Required Courses (12 units)

CENG 205 (Finite Element Methods I) (2)
CENG 206 (Finite Element Methods II) (2)
CENG 207 (Finite Element Methods III) (2)
MECH 325 (Computational Geometry for Computer-Aided Design and Manufacture I) (2)
MECH 326 (Computational Geometry for Computer-Aided Design and Manufacture II) (2)
MECH 415 (Optimization in Mechanical Design) (2)

Elective Courses (Select any 4 units)

AMTH 220 (Numerical Analysis I) (2)
AMTH 221 (Numerical Analysis II) (2)
AMTH 308 (Mathematical Modeling I) (2)
AMTH 309 (Mathematical Modeling II) (2)
AMTH 370 (Optimization Techniques I) (2)
AMTH 371 (Optimization Techniques II) (2)
CENG 211 (Advanced Strength of Materials) (4)
CENG 214 (Theory of Elasticity) (4)
CENG 222 (Advanced Structural Analysis) (4)
MECH 268 (Computational Fluid Mechanics I) (2)
MECH 269 (Computational Fluid Mechanics II) (2)

Dynamics

This certificate program includes a strong base in dynamics and vibrations and applications in optimization or dynamics of aircraft or spacecraft (depending on the chosen elective courses).

Required Courses (12 units)

MECH 203 (Analytical Dynamics I) (2)
MECH 204 (Analytical Dynamics II) (2)
MECH 205 (Introduction to Vibrations) (2)
MECH 214 (Advanced Dynamics I) (2)
MECH 215 (Advanced Dynamics II) (2)
MECH 216 (Advanced Dynamics III) (2)

Elective Courses (Select any 4 units)

MECH 223 (Inertial Instruments) (2)
MECH 429 (Optimization of Dynamic Systems I) (2)
MECH 430 (Optimization of Dynamic Systems II) (2)
MECH 431 (Aircraft Flight Dynamics and Performance) (2)
MECH 432 (Rocket and Spacecraft Dynamics) (2)

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Academic Information

STANDARDS OF SCHOLARSHIP

Only courses in which the student has earned assigned grades of A, B, or C, with plus (+) or minus (–) variations, may be counted for the master's degree. However, all grades are counted in computing the GPA. The student must earn a 3.0 average in all courses taken at Santa Clara as a graduate student to be eligible for the degree. Only credits, not grade points, are transferred from other institutions. A cumulative GPA of less than 2.6 after completion of 12 units will result in dismissal from graduate school.

GRADING SYSTEM

The grades A, B, C, and D may be modified by (+) or (–) suffixes, except that the grade of A may not be modified by a (+). Grade point values per unit are assigned as follows: A = 4.0; A– = 3.7; B+ = 3.3; B = 3.0; B– = 2.7; C+ = 2.3; C = 2; C– = 1.7; D+ = 1.3; D = 1.0; D– = 0.7; and F, I (incomplete), P (pass), NP (no pass), AUD (audit), NR (no grade reported by instructor—this notation is assigned by the Student Records Office)—and W (withdrawn) = 0. Unit credit, but not grade point credit, is awarded when the grade of P is assigned.

READMISSION/REGISTRATION

An application for readmission is required of persons whose enrollment in the University lapses for two consecutive terms, excluding summer terms. A regular admission form will be used with the readmission status marked on it. Applicants for readmission must submit transcripts of the latest graduate work completed in other University departments, together with official transcripts of study completed elsewhere since the previous enrollment.

After successfully completing requirements for any advanced degree, a student must reapply if interested in taking additional graduate engineering courses. None of the courses taken while earning the first degree will be allowed to transfer for any other subsequent degree.

Students who fail to register for two consecutive quarters will be considered inactive. Mail registration packets, however, are sent only to students who have enrolled the previous quarter. Students who desire mail registration may write or call the Graduate School of Engineering no later than one month prior to the beginning of mail registration (see Academic Calendar, Pages 6–8).

COURSE LOAD

It is recommended that work-study students limit their course load on initial registration to a maximum of 4 quarter hours. Regardless of the convenience of the class hours, the additional time required for study, coupled with other responsibilities, can make it very difficult to maintain high-quality work.

Resident students with a research or teaching assistantship will not be allowed to enroll in more than 12 quarter hours in any quarter. The minimum load for full-time enrollment is 8 quarter hours.

REPEATING COURSES

A student may, with the permission of the department, repeat a course in which a grade of C or lower was received on the first attempt. All grades, whether received on the first or second attempt, will be used in computing overall student performance. The units from a course may be counted only once in fulfilling graduation requirements.

COURSES COMPLETED AT OTHER INSTITUTIONS

A maximum of 9 quarter hours of credit may be transferred from other accredited institutions at the discretion of the chair of the department in which the student is seeking a degree. Eligible courses include those taken as a registered graduate student in which a grade of B or better was earned; however, only the units are transferred, not the grades.

Transfer units include only courses taken after receipt of the bachelor's degree and those not used for a previous degree. Santa Clara students seeking a second master's degree must complete an additional 45 quarter units.

Note: Official transcripts (two copies) must be on file before transfer units will be approved.

INTERNATIONAL STUDENTS

Admission to graduate study is based on records of undergraduate work. If the undergraduate work was done in a country where English is not the official language, a student is required to submit test scores on the Test of English as a Foreign Language (TOEFL). All students are required to submit Graduate Record Examination test scores. International students requesting Immigration Form I-20 must submit a financial statement showing adequate funds for tuition, fees, and living expenses for the entire program. The University will strongly encourage review courses in English and appropriate undergraduate courses, not for graduate credit, when it finds that an individual's progress is suffering because of a language difficulty.

Accepted international students will receive a letter of acceptance that they must show to the U.S. consular officer to whom they apply for a student visa. International students must be enrolled in at least 8 units per quarter.

WITHDRAWAL FROM COURSES/AUDITS

Students may change their course registration as stated in the Academic Calendar (Pages 6–8). Withdrawal from any course or change to audit may be accomplished up to the ninth Friday of the term. A withdrawal will be recorded as W on the transcript. After the ninth Friday, an emergency that qualifies may be handled as an incomplete (I) (see Pages 17–18). Dropping a course without formal withdrawal will result in a grade of F. Withdrawals after the first week of class must be completed in the Office of the Dean by the deadlines listed.

WITHDRAWAL FROM THE UNIVERSITY

Withdrawal from the University is not officially complete until students clear all of their financial obligations with the Office of Student Accounts. Students on deferments or Federal Perkins Loans must also clear their financial obligations with the Credit and Collections Office.

ENGINEERING HONOR CODE

The Engineering Honor Code is a long-standing Santa Clara tradition. Instituted at the request of engineering students, the code states: *All students taking courses in the School of Engineering agree, individually and collectively, that they will not give or receive unpermitted aid in examinations or other course work that is to be used by the instructor as the basis of grading.* Students and teachers cooperate and share responsibilities under the code. *Teachers* are responsible for making clear what aid is permissible and for using procedures that minimize temptations to violate the code. *Students* are responsible for behaving honorably, for actively ensuring that others as well as themselves uphold the code, and for being responsive to violations. *Students* dominate the administration of the code, and they take full responsibility for trying cases of alleged violations and for recommending penalties. Alleged violations should be reported to the Engineering Honor Code Committee. More information on the code and its procedures are contained in a leaflet available from the School of Engineering and the department offices.

STUDENT RECORDS

University policy relating to student records complies with the Family Educational Rights and Privacy Act of 1974 (Buckley Amendment). Accordingly, the University may release directory information to any person on request, unless a student requests in writing that directory information be kept confidential. A student's directory information is designated as follows:

1. Name
2. Gender
3. Address (campus, local and/or permanent)
4. Telephone number

5. Date and place of birth
6. Major field of study, classification, dates of attendance, degrees, and honors received
7. Most recent previous educational institution attended
8. Participation in officially recognized activities, including intercollegiate athletics
9. Name, weight, and height of participants on intercollegiate athletic teams

During the registration period and throughout the academic year, students may request in writing, through the Student Records Office, that directory information be kept confidential. Once filed, the request remains in effect only for the remainder of that academic year.

Certain records are excluded by the law from inspection, specifically those created or maintained by a physician, psychiatrist, or psychologist in connection with the treatment or counseling of a student. A Parents' Confidential Statement of the College Scholarship Service is also excluded by law from inspection. Third parties may not have access to educational records or other information pertaining to students without the written consent of the particular student about whom the information is sought.

Former or current borrowers of funds from any Title IV student loan program should note carefully that requests for nondisclosure of information will have no effect on preventing Santa Clara University from releasing information pertinent to employment, enrollment status, current address, and loan account status to a school lender, subsequent holder, guarantee agency, U.S. Department of Education, or an authorized agent.

Students may inspect their records at the following locations:

- Official academic records, including application forms, admissions transcripts, letters of acceptance, and a student's permanent academic record are on file and maintained in the Student Records Office.
- Working academic files are also maintained by the deans in their respective offices.
- Records related to a student's nonacademic activities are maintained in the Office of the Dean of Students.
- Records relating to a student's financial status with the University are maintained in the Student Records Office.

Students may direct complaints regarding academic records to the dean of the School of Engineering or to the registrar.

Students having questions regarding the policy on the privacy of records should contact the University registrar (Walsh Administration Building).

6

Financial Information

TUITION AND FEES, PER QUARTER

Application fee (one-time fee for graduate program applicants) ..... **$ 35**
This nonrefundable fee is to be sent with each application form.

Tuition, per unit for all courses, including thesis **$384**

Incremental tuition* ..... **$ 78**
(per quarter, for each student enrolled in Engineering School courses)

Registration fee ..... **$ 10**
This nonrefundable fee is payable each quarter of registration regardless of the number of units for which the student is registered.

Association of Graduate Engineering Students (AGES) fee ..... **$ 1**
(All matriculated students of the Graduate School of Engineering are members of AGES.)

Health Center fee, per quarter (all SCU health plan participants) ..... **$ 56**

Late payment fee ..... **$ 50**

Late registration fee (during add/drop period) ..... **$ 30**

Late registration fee (each registration adjustment after the add/drop period) ..... **$ 75**

Course drop fee (per course) ..... **$ 25**

Auditing fee, per quarter hour for all courses **$384**

Cooperative Education Program fee (per unit, per quarter) **$125**

Comprehensive written examination fee ..... **$ 10**

Dissertation microfilming, Ph.D. ..... **$ 45**

Academic transcript fee (per copy) ..... **$ 3**

Academic transcript fee (rush process) ..... **$ 8**

Deferment service fee ..... **$ 50**

Returned check fee ..... **$ 10**

*Tuition rate determined by school of admittance.

Parking permits (per year)..... **$ 40**
Parking permits (per quarter)..... **$ 20**

MANDATORY HEALTH INSURANCE

International students are required to show proof of health insurance coverage to waive purchase of the Santa Clara University–sponsored health insurance plan.

Annual international-student health insurance fee **$560**

METHOD OF PAYMENT

Tuition and fees are billed to the student. Any student who registers is obligated to pay tuition and fees by the published due date, even if he/she does not receive a bill. Courses will not be canceled because no payment was received for the quarter or because a student does not attend the class. If payment is not received or a proper deferment is not obtained through the Credit and Collection Office, the late payment fee (above) will be assessed and a hold will be placed on the account. The hold will prevent registration adjustments and the release of transcripts. Inquiries regarding account status should be directed to the Office of Student Accounting Services (408-554-4412). Remittances should be made payable to Santa Clara University, File 72662, P O Box 60000, San Francisco CA 94160-2662.

Students who have unpaid accounts at the University or who defer payment without approval are subject to dismissal from the University and will not be issued academic transcripts or diplomas as long as such accounts are outstanding.

TUITION REFUND POLICY

Fall, Winter, Spring Quarters Students may formally withdraw from class up to and including seven calendar days from the start of the quarter and receive a 100 percent tuition refund, less a $25 fee for each class dropped. The start of the quarter is considered to be the first date on which instruction begins for the School of Engineering.

Students who formally withdraw from a class after the first week of the quarter may receive a refund of tuition according to the following schedule:

Withdrawal during the second week of the quarter..... 50%
Withdrawal during the third week of the quarter 25%

No refunds will be authorized after the third week of the quarter.

Summer Session Students who formally withdraw from a class during summer session may receive a refund of tuition according to the following schedule:

Withdrawal during the first week of the session	100% less drop fee
Withdrawal during the second week of the session	50%

No refunds will be authorized after the second week of the session.

Any Quarter/Session No refunds will be made by virtue of curtailment of services brought about as a result of strikes, acts of God, civil insurrection, riots or the threat thereof, or other causes beyond the control of the University.

Refund checks for approved course withdrawal are issued by the Office of Student Accounts. Any student who qualifies for an institutional refund must request it from the Office of Student Accounts.

Note: All fees, charges, and refund schedules stated in this bulletin are subject to change without prior notice.

FINANCIAL AID

California State Graduate Fellowships

State graduate fellowships are awarded to students pursuing a recognized graduate or professional degree and who intend to pursue teaching as a career who have not completed more than four quarters of full-time graduate work as of Oct. 1. Selection is based on state manpower needs, academic performance, and financial need. Applications are available in January from the Financial Aid Office.

Loans

Students applying for aid may find the most advantageous method of financing their education through loan programs. Among those available to students of the School of Engineering are the Federal Perkins Loan and Federal Direct Loans. Application forms and further information may be obtained from the Financial Aid Office.

Deadlines

The Financial Aid Office has established deadlines for consideration of the various programs it administers. All students requesting financial aid from the University should contact the office at the earliest possible date to request specific deadline information and appropriate application materials. Files completed later than Feb. 1 for new recipients and March 2 for current recipients will receive consideration on a funds-available basis.

Veterans and Veterans' Dependents Assistance

Santa Clara University is listed by the Department of Veterans Affairs as qualified to receive students under Chapter 35 (veterans' dependents—son or daughter with parent deceased or 100 percent disabled, widow of any person who died in the service or died of a service-connected disability, or wife of a veteran with a 100 percent service-connected disability); Chapter 31 (rehabilitation); Chapter 30 (active duty Montgomery G.I. Bill); Chapter 34 (old G.I. Bill); and Chapter 32 (Post-Vietnam Era Veterans' Educational Assistance Program [VEAP]). Those interested in attending under any of these chapters should contact the Veterans Administration Office in their locality to determine eligibility for benefits.

The state of California provides a program for children of veterans who are deceased or disabled from service-connected causes. Application should be made to the California Department of Veterans Affairs, 350 McAllister St., San Francisco, CA 94102.

Information regarding these programs may be obtained from the Santa Clara University veterans' counselor located in the Student Records Office.

Teaching and Research Assistantships

A limited number of teaching and research assistantships are available. For further information, contact the Office of Graduate Admissions of the School of Engineering.

7

Engineering Facilities

The School of Engineering's laboratories are contained in three buildings in the Sullivan Engineering Center, originally built in 1960 and refurbished in 1985–86. Facilities are supported by the incremental tuition for engineering students.

GENERAL COMPUTING FACILITIES

The School of Engineering has over 60 Hewlett-Packard 9000 high-end workstations grouped into two large classrooms, together referred to as the Design Center. All workstations run Hewlett-Packard's version of the UNIX operating system and have high-resolution color graphics and a variety of software for computer-aided design (CAD) and analysis in civil, computer, electrical, and mechanical engineering, as well as a variety of programming languages.

In addition, Santa Clara provides mainframe and personal computing facilities to support educational programs. Free noncredit short courses for both types of computers are offered periodically. Computer labs are typically open from 8 a.m. to midnight Monday through Friday, with hours slightly reduced on weekends.

The principal academic mainframe system is a Digital Equipment Corporation VAX-6610 running under the VMS operating system. The system can be accessed from three public laboratory facilities and through 30 dial-up ports. Software includes nine programming languages (Ada, LISP, Prolog, Pascal, C, FORTRAN, COBOL, BASIC, and assembler), SPSS and SAS statistical packages, two simulation packages (SLAM and SIMSCRIPT), and the RDB relational database system.

PCs are concentrated in two general-purpose laboratories containing 150 IBM machines and various software packages for word processing, spreadsheet and database applications, and programming. Each PC can function as a terminal to the VAX.

Most of the academic computers are connected by Ethernet local area network (LAN), which provides high-speed communications among the various systems. Santa Clara is also a node on the Internet and BITNET wide-area networks, providing students and faculty with electronic mail, file transfer, and remote-access communications to more than 3,000 nodes in the United States, Canada, Europe, Japan, and other countries throughout the world.

CIVIL ENGINEERING LABORATORIES

The *Civil Engineering Laboratories* contain equipment and facilities to support research and teaching in materials engineering, structural engineering, stress analysis, soil mechanics, geology, transportation engineering and surveying, environmental quality, and hydraulics.

The *Computer Analysis and Design Laboratory* contains 386 and 486 personal computers that are used in course assignments and design projects. Technical software packages in all the major areas of civil engineering are maintained on the systems with full documentation available to students.

The *Concrete Testing Laboratory* contains facilities for mixing, casting, curing, and testing concrete samples.

The *Environmental Laboratory* is equipped with instrumentation needed for basic chemical and biological characterization of water, wastewater, and air samples. Several pilot-scale treatment systems are also available.

The *Geology Laboratory* is equipped with extensive rock and mineral samples as well as topographic, geologic, and soil maps.

The *Hydraulics Laboratory* is shared with the Mechanical Engineering Department. It contains a tilting flume that can be fitted with various open-channel fixtures.

The *Structures and Materials Laboratory* is equipped with five universal testing machines that are used for testing a variety of construction materials, including composites, steel, concrete, aluminum, and wood. The largest testing machine has a 1780-KN capacity. Small structural samples can be tested on low-capacity Instron or Applied Test Systems machines. A high-speed data acquisition and control system and a variety of digital and analog instruments are also available for material and structural testing. The laboratory also has a loading frame, which is used to accommodate custom test setups.

The *Soil Mechanics Laboratory* contains equipment for testing soils in shear, consolidation, and compaction and for other physical and chemical tests. Field testing and sampling equipment is also available. A complete cyclic triaxial testing system with computer control is used for both research and instructional purposes.

The *Surveying Laboratory* has a wide variety of equipment, such as self-leveling levels, transits, theodolites, and electronic distance-measuring devices available for instructional purposes.

The *Traffic Laboratory* has electronic volume counters that are used in studies to classify vehicles and measure their speeds in user-specified ranges and periods of time. This equipment is used for instructional and research purposes.

COMPUTER ENGINEERING LABORATORIES

The *ASIC Testing Laboratory* (ATL) supports research conducted by graduate students from the Electrical Engineering and Computer Engineering departments. Computer-aided testing packages from industry and the public domain are used in such projects as fault analysis on the device level, functional testability measures, partitioning HDL models for testability, and rapid prototyping using field programmable gate arrays (FPGAs).

The *Computer Systems and Parallel Processing Research Laboratory* supports research in systolic array design, interconnection networks, parallel operating systems, formal design verification, expert system development for architectural design, parallel software development methodology, application-oriented parallel algorithms, and VLSI design.

The *Digital Systems Laboratory* (operated jointly with the Electrical Engineering Department) provides complete facilities for experiments and projects ranging in complexity from a few digital integrated circuits and other electronic components to complete computer systems. It includes a variety of development systems to support microprocessor-based design, VLSI design, and other computer design projects. It also holds facilities to support digital signal processing projects.

The *Distributed Computing Research Laboratory* is designed to support a variety of research activities in distributed computing, including parallel architectures; parallel applications; high-performance, high-speed, local area networks; lightweight protocols; and distributed operating systems.

The *Object Technology Laboratory* (OTL) is a center for research and education in all aspects of object technology, which is a new paradigm in software system design, development, and implementation. Sponsored research projects conducted at OTL address the theoretical development and application of object technology. Advanced seminars and short courses sponsored by OTL provide an opportunity to learn about the latest developments in object technology.

The *Signal and Digital Image Processing Laboratory* (operated jointly with the Electrical Engineering Department) conducts research in theoretical issues in image processing, image analysis, three-dimensional modeling from two-dimensional data, and nonlinear signal processing. Applications include medical image analysis, two- and three-dimensional image reconstruction, and passive navigation for robotic vision.

The *Software Engineering Research Laboratory* is a dedicated facility for the support of various research activities aimed at developing engineering techniques and tools that help produce and validate high-quality software. Specific research activities include formal specification and verification methods/tools, design framework for concurrent systems; Case architect, logic programming paradigms, and automatic reasoning.

The *Storage Technology Laboratory* is used primarily for graduate research, although senior projects are encouraged and supported. Facilities include a separate laboratory area with a state-of-the-art Guzik test stand and associated instrumentation for high-density magnetic head and disk studies with capabilities to digitize readback signals and utilize them to evaluate simulation models of the recording channel; an HP 750 workstation linked to the School of Engineering Design Center; and advanced computers and software. Research areas include: studies on novel silicon planar heads; advanced recording channels based on digital signal processing such as PRML; and the high-date disk-drive architectures that are envisaged with the growth of multimedia applications. The laboratory is part of an Industry/University Consortium that is pursuing government-funded research to achieve 10-GB/square-inch recording densities by the end of the decade. Research is being pursued as part of this program.

ELECTRICAL ENGINEERING LABORATORIES

The *ASIC Testing Laboratory* (ATL) supports research conducted by graduate students from the Electrical Engineering and Computer Engineering departments. Computer-aided testing packages from industry and the public domain are used in such projects as fault analysis on the device level, functional testability measures, partitioning HDL models for testability, and rapid prototyping using field programmable gate arrays (FPGAs).

The *Digital Systems Laboratory* (operated jointly with the Computer Engineering Department) provides complete facilities for experiments and projects ranging in complexity from a few digital integrated circuits and other electronic components to complete computer systems. It includes a variety of development systems to support microprocessor-based design, VLSI design, and other computer design projects. It also holds facilities to support digital signal processing projects.

The *Intelligent Control Laboratory* includes two IBM robotic arm systems, IBM 486 PCs, and several servo-experimenters with computer support systems.

The *Microelectronics Laboratory* provides teaching and research facilities for semiconductor devices and integrated circuit design, fabrication, and characterization. Ongoing research topics include silicon heterostructures, thin dielectrics, and high-temperature superconductors on silicon devices.

The *Microwave and Communications Laboratory* provides a full range of modern measurement capability from 0–22 GHz, including a number of automatic network analyzers and modern spectrum analyzers. It also has extensive computer-aided design and simulation capability, based largely on modern commercial software running on workstations. Interconnection of hardware measurements and computer simulation is stressed.

The *Signal and Digital Image Processing Laboratory* (operated jointly with the Computer Engineering Department) is used primarily for graduate research. It has a Sun 3/280, Sun SPARC server 630, and SPARC workstations, one of which has 24-bit color, a stereo display, and image digitization capability. Texas Instruments TMS320 systems are used for real-time signal processing. Research areas include theoretical issues in image processing, image analysis, three-dimensional modeling from two-dimensional data, adaptive signal processing, artificial neural networks, and nonlinear signal processing. Applications include medical image analysis, two- and three-dimensional image reconstruction, passive navigation for robotic vision, and VLSI implementations of adaptive signal processing.

The *Storage Technology Laboratory* is used primarily for graduate research, although senior projects are encouraged and supported. Facilities include a separate laboratory area with a state-of-the-art Guzik test stand and associated instrumentation for high-density magnetic head and disk studies with capabilities to digitize readback signals and utilize them to evaluate simulation models of the recording channel; an HP 750 workstation linked to the School of Engineering Design Center; and advanced computers and software. Research areas include: studies on novel silicon planar heads; advanced recording channels based on digital signal processing such as PRML; and the high-date disk-drive architectures that are envisaged with the growth of multimedia applications. The laboratory is

part of an Industry/University Consortium that is pursuing government-funded research to achieve 10-GB/square-inch recording densities by the end of the decade. Research is being pursued as part of this program.

MECHANICAL ENGINEERING LABORATORIES

The *Mechanical Engineering Laboratories* contain facilities for instruction and research in the fields of fluid mechanics, thermodynamics, heat and mass transfer, propulsion, combustion, power generation, shock and vibration, instrumentation, control systems, materials science, and manufacturing.

A variety of internal combustion engines installed on dynamometer stands can be used for studies in diesel and spark-ignition engines. The facilities include instrumentation for evaluating engine performance, measuring exhaust pollutants, and measuring noise. Engine studies can be conducted using a variety of fuels.

The fluid dynamics facilities contain equipment to illustrate the principles of fluid flow and to familiarize students with hydraulic machines and their associated instrumentation. Each device may be supplied from a pump or from a constant-level standpipe with a 25-foot head. A subsonic wind tunnel equipped with an axial flow fan with adjustable blades is available to conduct experiments in aerodynamics and turbomachinery.

Included also in the Mechanical Engineering Laboratories is equipment to study electromechanical energy conversion and response and control of mechanical systems. The metallurgy laboratory features a modern scanning electron microscope that is used to familiarize students with properties of materials. The machine shop is equipped with manual mills, lathes, and a Haas CNC mill for student instruction, construction of experimental devices, and student projects.

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Course Descriptions

SCHOOL OF ENGINEERING

Dean: Terry E. Shoup
Associate Dean: Samiha Mourad

The following courses are interdisciplinary in nature:

200. English for International Students

English for international students in engineering. Effective technical writing, communication, and presentation. P/NP grading. (2 units)

201. The Culture of Engineering

Study of the relation of human life and society to engineering. Philosophy of science and engineering. Engineering ethics. Includes extensive relevant readings in myth and in the classics. (2 units)

DEPARTMENT OF APPLIED MATHEMATICS

Professor Emeritus: Gerald E. Markle
Associate Professor: George R. Fegan *(Chair)*

UNDERGRADUATE COURSES

106. Differential Equations

First-order linear differential equations, systems of linear differential equations, homogeneous systems of linear differential equations with constant coefficients, the Laplace transform, the solution of differential equations by Laplace transform. *Prerequisite: Math 21.* (4 units)

108. Probability and Statistics

Definitions of probability, sets, sample spaces, conditional and total probability, random variables, distributions, functions of random variables, sampling, estimation of parameters, testing hypotheses. *Prerequisite: Math 21.* (4 units)

118. Numerical Methods

Numerical solution of algebraic and transcendental equations, finite differences, numerical differentiation and integration, and solution of ordinary differential equations. Solution of representative problems on the digital computer. *Prerequisites: ability to program in some computer language, COEN 44, Math 21, and AMTH 106.* (4 units)

GRADUATE COURSES

All 200-level applied mathematics courses are assumed to be first-year graduate courses. The minimum preparation for these courses is a working knowledge of calculus and a course in differential equations. A course in advanced calculus is desirable. The 300-level courses are graduate courses in mathematics that should be taken only by students who have completed several 200-level courses.

202. Mathematical Methods in Mechanical Engineering

Analytic solution of ordinary differential equations. Fourier series. Analytic solution of linear partial differential equations by separation of variables. Numerical solution of ordinary differential equations by iterative and direct methods. Introduction to numerical solution of partial differential equations using explicit, implicit, ADI, and relaxation-type methods. Eigenvalue problems. Introduction to complex variables. (Also listed as MECH 202.) (2 units)

210. Introduction to Probability I

Definitions, sets, conditional and total probability, binomial distribution approximations, random variables, important probability distributions, functions of random variables, moments, characteristic functions, joint probability distributions, marginal distributions, sums of random variables-convolutions, correlation, sequences of random variables, limit theorems. (2 units)

211. Introduction to Probability II

Continuation of AMTH 210. *Prerequisite: AMTH 210.* (2 units)

214. Engineering Statistics I

Frequency distributions, sampling, sampling distributions, univariate and bivariate normal distributions, analysis of variance, two- and three-factor analysis, regression and correlation, design of experiments. *Prerequisite: a course in probability.* (2 units)

215. Engineering Statistics II

Continuation of AMTH 214. *Prerequisite: AMTH 214.* (2 units)

216. Product Reliability Modeling

Statistical models for reliability. Binomial, normal, lognormal, gamma, Weibull, and exponential models. Availability and spares. Stress-strength analysis. Plotting papers, censored data, electronic systems, and software reliability. Prior exposure to statistics useful but not essential. *Prerequisite: a course in probability.* (2 units)

217. Design of Scientific Experiments

Statistical techniques applied to scientific investigations. Use of reference distributions, randomization, blocking, replication, analysis of variance, Latin squares, factorial experiments, and examination of residuals. Prior exposure to statistics useful but not essential. *Prerequisite: a course in probability.* (2 units)

218. Process Troubleshooting and Control

Statistical methods applied to control and troubleshoot processes. Various control charts and operating characteristic curves. Analysis of means applied to both variables and attribute data. Narrow-limit gauging, sampling, disassembly and reassembly, outliers and outgoing product quality rating. Prior exposure to statistics useful but not essential. *Prerequisite: a course in probability.* (2 units)

219. Analysis of Scientific Experiments

Continuation of AMTH 217. Emphasis on analysis of the scientific experiments. The theory of design of experiments so that maximal information can be derived. *Prerequisites: AMTH 211 and 217.* (2 units)

220. Numerical Analysis I

Solution of algebraic and transcendental equations, finite differences, interpolation, numerical differentiation and integration, solution of ordinary differential equations, matrix methods with applications to linear equations, curve fittings, programming of representative problems. (2 units)

221. Numerical Analysis II

Continuation of AMTH 220. *Prerequisite: AMTH 220.* (2 units)

225. Vector Analysis I

Algebra of vectors. Differentiation of vectors. Partial differentiation and associated concepts. Integration of vectors. Applications. Basic concepts of tensor analysis. (2 units)

226. Vector Analysis II

Continuation of AMTH 225. *Prerequisite: AMTH 225.* (2 units)

230. Applied Mathematics I

Orthogonal functions. Fourier series. Solution of ordinary differential equations by series. Legendre polynomials. Laplace transforms, basic transforms, applications. Gamma and beta functions. Bessel functions. (2 units)

231. Applied Mathematics II

Continuation of AMTH 230. *Prerequisite: AMTH 230.* (2 units)

235. Complex Variables I

Algebra of complex numbers, calculus of complex variables, analytic functions, harmonic functions, power series, residue theorems, application of residue theory to definite integrals, conformal mappings. (2 units)

236. Complex Variables II

Continuation of AMTH 235. *Prerequisite: AMTH 235.* (2 units)

240. Modern Algebra I

Introduction to postulational systems; study of integral domains, fields, and rings; special emphasis on group theory and applications. Polya theory and coding theory; Boolean algebra and its relation to switching functions; general theory of lattices. (2 units)

241. Modern Algebra II

Continuation of AMTH 240. *Prerequisite: AMTH 240.* (2 units)

242. Modern Algebra III

Continuation of AMTH 241. Special topics in the application of group theory and lattice theory. *Prerequisite: AMTH 241.* (2 units)

245. Linear Algebra I

Vector spaces, transformations, matrices, characteristic value problems, canonical forms, and quadratic forms. (2 units)

246. Linear Algebra II

Continuation of AMTH 245. *Prerequisite: AMTH 245.* (2 units)

280. Combinatorial Mathematics I

Permutations, combinations, partitions, enumeration methods, generating functions, evaluation of discrete sums, and introduction to graph theory. Recurrence relations, solution of difference equations, the principle of inclusion and exclusion, Polya theory of counting. Applications. Knowledge of matrices suggested. (2 units)

281. Combinatorial Mathematics II

Continuation of AMTH 280. *Prerequisite: AMTH 280.* (2 units)

299. Special Problems

By special arrangement. (1–2 units)

305. Advanced Numerical Analysis I

Numerical solution of partial differential equations, finite difference methods.

Monte Carlo techniques, relaxation methods, programming of representative problems. *Prerequisites: AMTH 220 and 221 and the ability to program in some computer language.* (2 units)

306. Advanced Numerical Analysis II

Matrix computations, eigenvalues of finite matrices, application of matrix methods to the solution of systems of linear equations, programming of representative problems. *Prerequisites: AMTH 220 and 221 or equivalent.* (2 units)

308. Theory of Wavelets

Construction of Daubechies' wavelets and the application of wavelets to image compression and numerical analysis. Multiresolution analysis and the properties of the scaling function, dilation equation, and wavelet filter coefficients. Pyramid algorithms and their application to image compression. (2 units)

310. Linear Statistical Models

Basic and multifactor analysis of variance (ANOVA); single-factor analysis; two-factor studies; multifactor studies; analysis of randomized block design, Latin Square design, and factorial design. *Prerequisite: AMTH 211.* (2 units)

312. Nonparametric Statistics

Assumptions of parametric statistics. Nonparametric and distribution-free approaches. Single-sample procedures. Methods for independent or related multiple samples. Tests for independence, homogeneity, or goodness-of-fit. Rank correlation and other measures of association. *Prerequisite: AMTH 211.* (2 units)

313. Time Series Analysis

Review of forecasting methods. Concepts in time series analysis; stationarity, autocorrelation, Box-Jenkins. Moving average and autoregressive processes. Mixed processes. Models for seasonal time series. *Prerequisite: AMTH 211.* (2 units)

315. Matrix Theory I

Properties and operations, vector spaces and linear transforms, characteristic root; vectors, inversion of matrices, applications. *Prerequisite: AMTH 245.* (2 units)

316. Matrix Theory II

Continuation of AMTH 315. *Prerequisite: AMTH 315.* (2 units)

330. Advanced Applied Mathematics I

Functional spaces, vector and matrices, systems of orthogonal functions, linear spaces, manifolds, linear operators, spectral theory, functions of operators and matrices. Green's functions, delta functions, differential operators, eigenfunction representation of operators, perturbation methods, operators for partial differential equations. (2 units)

331. Advanced Applied Mathematics II

Continuation of AMTH 330. *Prerequisite: AMTH 330.* (2 units)

332. Difference Equations

Definition of difference equations, standard techniques for solution of difference equations, numerical approximations to solutions of difference equations; applications: pendulum problem, predator-prey problems. Bessel and Legendre applications, phasers as applied to chaos theory. *Prerequisite: AMTH 211.* (2 units)

334. Numerical Algorithm Development for Computer Applications I

Develops topics introduced initially in courses in discrete mathematics, number theory, combinatorics, recursion theory, probability, and asymptotic methods. Intended for computer scientists and other students who are interested in mathematical problems that arise in computer applications. The material corresponds to that presented in Donald Knuth's *The Art of Computer Programming.* The first quarter

includes topics in recursion, manipulation of sums, integer functions, and number theory. *Prerequisite: discrete mathematics or AMTH 240.* (2 units)

335. Numerical Algorithm Development for Computer Applications II

Continuation of AMTH 334. Intended for computer scientists and other students who are interested in mathematical problems that arise in computer applications. Topics include generating functions, convolutions, hypergeometric functions, probability generating functions, and selections from asymptotic theory. *Prerequisite: AMTH 334.* (2 units)

340. Linear Programming I

Basic assumptions and limitations, problem formulation, algebraic and geometric representation. Simplex algorithm and duality. (2 units)

341. Linear Programming II

Continuation of AMTH 340. Network problems, transportation problems, production problems. *Prerequisite: AMTH 340.* (2 units)

344. Linear Regression

The elementary straight-line "least squares fit"; the fitting of data to linear models. Emphasis on the matrix approach to linear regressions. Multiple regression; various strategies for introducing coefficients. Examination of residuals for linearity. Introduction to nonlinear regression. *Prerequisite: AMTH 211.* (2 units)

346. Graph Theory I

Introduction to graph theory; Euler paths and their applications; Hamiltonian circuits; trees, circuits, and cut-sets; shortest-path problems; planarity and duality; matching theory; directed graphs. *Prerequisite: knowledge of matrix theory.* (2 units)

347. Graph Theory II

Continuation of AMTH 346. *Prerequisite: AMTH 346.* (2 units)

358. Fourier Transforms

Definition and basic properties. Energy and power spectra. Applications of transforms of one variable to linear systems, random functions, communications. Transforms of two variables and applications to optics. (2 units)

362. Stochastic Processes I

Types of stochastic processes, stationarity, ergodicity, differentiation and integration of stochastic processes, correlation and power spectral density functions, linear systems, band limit processes, estimation, nonstationary processes, normal processes, Markov processes. *Prerequisite: AMTH 211.* (2 units)

363. Stochastic Processes II

Continuation of AMTH 362. *Prerequisite: AMTH 362.* (2 units)

370. Optimization Techniques I

Optimization techniques with emphasis on experimental methods. One-dimensional search methods. Multidimensional unconstrained searches: random walk, steepest descent, conjugate gradient, variable-metric. *Prerequisites: ability to program in FORTRAN or similar language and AMTH 246 or equivalent.* (2 units)

371. Optimization Techniques II

Optimization problems in multidimensional spaces involving equality constraints and inequality constraints by gradient and nongradient methods. Special topics. *Prerequisite: AMTH 370.* (2 units)

374. Partial Differential Equations I

Relation between particular solutions, general solutions, and boundary values. Existence and uniqueness theorems. Wave equation and Cauchy's problem. Heat equation. *Prerequisites: AMTH 230 and 231.* (2 units)

375. Partial Differential Equations II

Continuation of AMTH 374. *Prerequisite: AMTH 374.* (2 units)

380. Queueing Systems I

Systems of flow. Notation and structure for basic queueing systems. Discrete-time and continuous-time Markov chains. Birth-death processes. Birth-death queueing systems in equilibrium: discouraged arrivals, responsive servers, m-server case, finite storage, finite customer population, and combinations of these cases. Markovian queues in equilibrium: bulk arrival system, bulk service system, Erlangian distribution, networks of Markovian queues. Introduction to advanced queueing systems. *Prerequisites: AMTH 210, 211, and 362.* (2 units)

381. Queueing Systems II

Direct applications of queueing theory in the areas of operating systems design, processor performance evaluation, and design of computer networks. *Prerequisite: AMTH 380.* (2 units)

DEPARTMENT OF CIVIL ENGINEERING

Professors: E. John Finnemore, Sukhmander Singh *(Chair)*
Associate Professors: Steven C. Chiesa, Paul J. Tikalsky
Assistant Professors: Salameh A. Nsour, Reynaud L. Serrette

In the Department of Civil Engineering, the fields of structural engineering and engineering mechanics are emphasized at the graduate level. The focus of the educational effort is on the experimental, analytical, and design methods used to evaluate and predict the behavior and performance of structural and other engineering systems. Advanced topics related to the static, dynamic, and stability response of structural systems are studied in the program.

UNDERGRADUATE COURSES

10. Surveying

Survey instruments: their use and care. Principles of topographic mapping, linear measurements, leveling, traverses, curves, boundary, and public surveys. Field laboratory. (4 units)

20. Geology

Development and formation of geologic materials. Significance of structure, land form, erosion, deposition. Stream and shoreline processes. Surface water. Laboratory. (4 units)

41. Mechanics I: Statics

Resolution and composition of force systems and equilibrium of force systems acting on structures and mechanisms. Distributed forces. Friction. *Prerequisites: Physics 4 and MECH 10.* (4 units)

42. Mechanics II: Dynamics

Dynamics of a particle and dynamics of rigid bodies. Work and energy methods. Momentum methods. Kinetics of systems of particles. Introduction to theory of vibrations. *Prerequisite: CENG 41.* (4 units)

43. Mechanics III: Strength of Materials

Analysis of stresses and strains in machines and structural members. Axial forces, torsion, bending, and combined loads. Stability of columns. Energy theorems and their applications. Laboratory. *Prerequisite: CENG 41.* (5 units)

115. Civil Engineering Materials

Origin, manufacture, and processing of materials used in civil engineering. Physical properties of metals, wood, plastics, cement, concrete, and other engineering materials. Laboratory. *Prerequisite: Chemistry 6.* (4 units)

118. Construction Engineering

Construction management. Equipment. Drawings and specifications, cost estimating, bidding. Contracts, bonds, financing, insurance. Labor. Project planning and scheduling. *Prerequisite: junior standing.* (3 units)

121. Geotechnical Engineering

Origin, development, and properties of soils. Classification of soils and applications of engineering mechanics to soils as an engineering material. Water in soils. Soil-testing methods. Compaction, stabilization, consolidation, shear strength, and slope stability. Laboratory. *Prerequisites: CENG 20 and 43.* (4 units)

125. Municipal Engineering Design

Various aspects of civil engineering as applied in municipal (public works) design practice. Maps and plats; site layout and earthworks; drainage; streets and utilities. Design laboratory. *Prerequisites: CENG 10 and MECH 122.* (4 units)

128. Engineering Economics

Time value of money. Economic analysis of engineering projects. Planning and capital budgeting. Rate-of-return analysis. Depreciation. Cash-flow analysis. (2 units)

132. Structural Analysis

Analysis of statically determinate beams, trusses, and frames. Influence lines for beams. Deflections computed using moment area, virtual work, and other analytical methods. Introduction to statically indeterminate analysis using stiffness and flexibility methods. Introduction of computer applications methods. *Prerequisite: CENG 43.* (4 units)

133. Timber Design

Review of timber structural systems. Design of structural members for tension, compression, bending, and shear. Design of shear walls and diaphragms. Timber design project required. *Prerequisite: CENG 132.* May be taken for graduate credit. (4 units)

134. Structural Steel Design

LRFD concepts of structural steel design for buildings and other structures. Types of loading. Design of individual members including tension members, beams, and columns. Introduction to connection design. Steel design project is required. *Prerequisite: CENG 132.* (4 units)

135. Reinforced Concrete Design

Analysis and design of reinforced concrete structural elements using the ultimate strength method. Design of elementary structures using ACI code methods. Design laboratory. *Prerequisite: CENG 132.* May be taken for graduate credit. (5 units)

136. Advanced Concrete Design

Analysis and design of structural elements such as long columns, retaining walls, cylindrical tanks, and shear members, involving reinforced concrete and prestressed concrete. Advanced topics in reinforced concrete design. *Prerequisite: CENG 135.* May be taken for graduate credit. (4 units)

137. Earthquake Engineering Design

Introduction to the source, propagation, and measurement of seismic activity and its effect on structures. Introduction to UBC and SEAOC provisions for seismic design. Special considerations for earthquake-resistant design of steel, timber, and reinforced-concrete structures. *Prerequisite: CENG 132.* May be taken for graduate credit. (4 units)

138. Geotechnical Engineering Design

Foundation exploration; bearing capacity and settlement analysis; spread foundations; piles and caissons; earth-retaining structures; loads on underground conduits; subsurface construction. *Prerequisites: CENG 121 and 135.* May be taken for graduate credit. (4 units)

139. Groundwater Hydrology

Groundwater occurrence, flow principles, flow to wells, regional flow. Groundwater contamination, management, and models. Field methods. Field trips. Laboratory. *Prerequisite: MECH 122.* (3 units)

140. Water Resources Engineering

Concepts of various aspects of water resources: surface water, groundwater, water supply and distribution, hydraulic structures and irrigation. Physical hydrology. Interrelationship of all aspects. Importance of water resources to the total needs of the community. Laboratory. *Prerequisite: MECH 122.* (4 units)

141. Hydraulic Engineering

Principles of hydraulics; flow in pipes and pipe networks; water hammer and surge tanks; steady flow in open channels; forces due to fluid flow. *Prerequisite: MECH 122.* (4 units)

142. Water Resources Design

Design of system components for water supply and flood control projects including storage facilities, closed conduits, open channels, well fields, and pumping systems. Computer applications in the design and evaluation of water resources–related facilities. *Prerequisites: CENG 140 and 141.* (4 units)

143. Environmental Engineering

Water and air quality. Water supply and pollution control; air pollution control. Management of solid and hazardous wastes. Laboratory. *Prerequisites: Chemistry 6 or equivalent and junior standing.* (4 units)

144. Environmental Systems Design

Design of treatment and distribution systems for potable water. Design of collection and treatment systems for water pollution control and wastewater reclamation. Laboratory. *Prerequisites: CENG 141 and 143.* (4 units)

145. Transportation Engineering Design

Transportation systems analysis and design. Traffic flow. Geometric design of systems. Principles of highway design. Planning, construction, and operation of transportation systems. Transportation policies and economics. *Prerequisites: CENG 10 and junior standing.* (4 units)

147. Pavement Design

Paving materials. Geometric and structural design of highways. Urban street layout and details. Layout and design of airport runways. *Prerequisites: CENG 121 and 135.* (4 units)

148. Structural Systems

Introduction to principles of material selection, choice of structural configuration, and structural design of building structures as 3-D systems. Discussion of fire protection. Estimation of design loads. Approximate techniques for system design and evaluation. Horizontal and vertical subsystems. *Prerequisite: CENG 43.* (3 units)

150. Traffic Engineering: Design and Operations

Basic characteristics of motor-vehicle traffic, highway and intersection capacity, applications of traffic control devices, traffic design of parking facilities, engineering studies, signal design, traffic safety, design of crash barriers. *Prerequisite: CENG 145.* May be taken for graduate credit. (4 units)

188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work ex-

perience relating to their academic field of study and career objectives. Alternate or parallel periods of classroom study with periods of training in industry and government. Work includes overall report on assignment activities. P/NP grading. May be taken for graduate credit. Additional fees required. (2 units)

189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or a research project, etc., after completing the co-op assignment. Approval of department co-op adviser required. Letter grades based on content and presentation quality of report. May be taken for graduate credit. (2 units)

192. Civil Engineering Design Methods

Introduction to problem-solving methodology for design of civil engineering systems and components. Applications of engineering techniques and procedures to civil engineering design. Preliminary design studies and evaluation of alternatives. Environmental impact assessment. Selection of a topic for Senior Design Project (CENG 193) and initial conceptual design. *Prerequisites: senior standing and English 182.* (2 units)

193. Senior Design Project

Investigation of an approved civil engineering project. The design process—including problem formulation, analysis, preliminary design, final design, and plans—is completed. Students present results at Senior Design Conference. *Prerequisite: CENG 192.* (4 units)

198. Internship

Time off campus with an engineering organization. Different aspects of work in the assigned professional office. Oral and written reports. *Prerequisites: senior standing and approval of internship coordinator.* (4 or 8 units)

199. Directed Research

Investigation of an approved engineering problem and preparation of a suitable project report. Conferences with faculty adviser are required. *Prerequisite: senior standing.* (2–6 units)

GRADUATE COURSES

205. Finite Element Methods I

Introduction to the finite element method. Force and stiffness methods. Matrix methods of analysis. Stiffness matrix formulation for axial and bending members. Local and global stiffness matrices. Transformation of stiffness matrices. (2 units)

206. Finite Element Methods II

Energy methods. Displacement functions for structural members. Derivation of load vectors. Analysis of plane stress and plane strain problems. Area coordinates. Constant strain triangle. Isoparametric elements. *Prerequisite: CENG 205.* (2 units)

207. Finite Element Methods III

Application of finite element method to dynamics of elastic and inelastic bodies. Mass matrices. Analysis of plates and shells. Development of computer code based on finite element theory. *Prerequisite: CENG 206.* (2 units)

209. Thin Plates and Shells

Methods of analysis of plates of various shapes under various loading and support conditions. Fourier series solutions, energy methods, and numerical finite difference methods. Membrane theory of shells of revolution. Bending theory of cylindrical shells. (4 units)

210. Behavior of Metal Structures

Introduction to first- and second-order analyses of steel structures. Critical review of the design provisions given in the AISC-LRFD Specification for Structural Steel Buildings. Approximate design techniques for steel structures. (2 units)

211. Advanced Strength of Materials

Bending of beams with nonsymmetrical cross section. Curved beams. Shear center. Shear flow in open and closed sections. Torsion of open and closed section members. Energy theorems and their applications. Beams on elastic foundations. Beam analysis using Fourier series. Stress analysis of composite materials. (4 units)

212. Variational Methods in Mechanics

Introduction to fundamental variational principles. Virtual work, minimum and complementary potential energy. Reissner's and Hamilton's principles. Applications to the formulation of governing differential equations and boundary conditions for problems in engineering mechanics. (2 units)

214. Theory of Elasticity

Analysis of stress and strain using Cartesian tensors. Compatibility conditions and the uniqueness theorem. Tensor-stress function and Boussinesq-Papkovitch displacement potentials. Applications to boundary value problems in three-dimensional elasticity. (4 units)

215. Advanced Construction Materials

Design concepts and behavior of construction materials. Properties related to long-term serviceability, deformation, strength, and failure modes. Physical and chemical properties and environmental limitations. High alloy steel, high-performance concretes, polymers, geotextiles, composites, fabrics, fibers, anchors, and cables. (2 units)

216. Theory of Plasticity

Stress and strain analysis of members whose material is loaded beyond the plastic limit. Perfectly plastic materials. Yield hinges. Yield criteria, slip-line folds. Elastic-plastic analysis of spheres and cylinders. Creep behavior of materials. (2 units)

217. Advanced Theory of Shells

Bending theory of shells. Stress function and numerical methods in shell analysis. Shells of negative curvature and shallow shells. Shells of variable thickness. *Prerequisite: CENG 209.* (2 units)

218. Structural Dynamics

Analysis and behavior of simple linear oscillators. Natural mode shapes and frequencies for distributed and lumped mass systems. Introduction to nonlinear vibrations. (4 units)

219. Advanced Dynamics

Continuation of CENG 218. Distributed parameter systems. Nonlinear transient dynamics. Dynamic response in the frequency domain. Component mode methods. *Prerequisite: CENG 218.* (2 units)

221. Stability of Structures

Energy methods. Elastic stability of columns under axial loads and bending moments. Introduction to inelastic stability analysis of columns. Stability analysis of frames. Stability of flat plates and cylindrical shells. Lateral buckling of beams. (4 units)

222. Advanced Structural Analysis

Advanced methods for the analysis of statically indeterminate structures. Comparison of analysis methods. Analysis by approximate and energy methods. Flexibility and stiffness methods suitable for computer implementation. (4 units)

226. Plastic Theory of Structures

Concepts of plastic behavior of structures. Collapse mechanisms for beams and

frames. Applications of energy methods in solution procedures. (2 units)

227. Experimental Stress Analysis

Theory and practice of the photoelastic and Moire methods for determining stresses. Photoelastic coatings. Electrical, mechanical, and optical strain gauges. (2 units)

228. Fracture Mechanics of Solids

Elastic and elastic-plastic fracture criteria. Stress intensity solutions. Metallurgical aspects of toughness. Design and alloy selection. Failure analysis techniques applied to actual engineering problems. (2 units)

229. Mechanical Properties of Materials

Structure of alloyed metals and other crystalline materials. Behavioral theories for engineering materials at low and elevated temperatures. Fatigue and creep behavior. Effect of radiation on mechanical properties. (2 units)

233. Timber Engineering

Design of industrial timber structures. Design of wood diaphragms, framing systems, and trusses. Design of glue-laminated long-span members and connections. A project is required. (2 units)

234. Advanced Steel Structures

Detailed design of rigid, semirigid, and simple connections. Design for local and overall buckling in beams and columns. Introduction to torsion. (2 units)

235. Advanced Concrete Structures

Analysis and design of concrete buildings. Design considerations include seismic detailing shear-wall design and prestressed concrete design. Discussion of ACI code and commentary. *Prerequisite: CENG 135.* (4 units)

238. Earthquake Engineering I

Single- and multi-degree-of-freedom systems. Transient response to free vibration and damped systems. Response and design spectra. Primary design considerations and lateral load-resisting system design. (2 units)

239. Earthquake Engineering II

Continuation of CENG 238. Seismic detailing. Concrete detailing—steel requirements, hooks, development lengths, anchors, shear walls, and continuity. Steel detailing—moment-resisting connections, bracing, bridge connections, cable restrainers. Example problems and case studies. Timber detailing—strong ties, tie downs, beam-column connections. Masonry design considerations. *Prerequisite: CENG 238.* (2 units)

240. Composite Structures

Lamination theory. Constitutive relationships. Laminate failure behavior. Testing of composite materials. Theory and design of adhesive and bolted joints. Structural behavior of composites. (4 units)

241. Reliability of Engineering Systems

Introduction to general schemes for reliability assessment of structural systems, structural members, and components. Probability models for loading, mechanical properties of materials, geometrical characteristics, and strength. Selection and application of reliability models. Imperfection-sensitive reliability models. (2 units)

242. Soil-Structure Interaction

Introduction of soil-structure analysis for evaluating seismic response. Dynamic interaction between the structure and its surrounding soil. Soil-structure interaction models. (2 units)

244. Nonlinear Elasticity

Field equations of nonlinear elastostatics and elastodynamics. Application of the field equations to special problems. Stability and linearization methods. Introduction to static bifurcation problems. (2 units)

246. Masonry Engineering

Design of unreinforced and reinforced masonry structures, including shear-wall and bearing-wall systems. (2 units)

247. Cold-Formed Steel and Aluminum Design

Introduction to the behavior of thin-walled structural components. Design of cold-formed steel and aluminum component elements for tension, compression, and bending. (2 units)

248. Plate Girder and Composite Design

Detailed design of plate girders, including tension field action. Introdution to steel-concrete composite construction. Design of composite structural components and systems. (2 units)

250. Traffic Engineering: Design and Operations

Basic characteristics of motor vehicle traffic; highway and intersection capacity; applications of traffic-control devices. Traffic design for parking structures; signal design. Traffic safety; design of crash barriers. *Prerequisite: CENG 145.* (4 units)

256. Public Transportation

Evolution of mass transit in the United States. Characteristics of major components of mass transit: bus, light- and rapid-rail transit. Prominent systems of mass transit in selected major U.S. cities. Paratransit systems. Financing and administering of transit and paratransit systems. New technology applications in mass transit. Course requires students to get hands-on experience on one of the major transit systems in the Bay area as a study case. (3 units)

297. Thesis Research

By special arrangement. (1–9 units)

299. Independent Study

Special/advanced topics. By special arrangement. (1–6 units)

DEPARTMENT OF COMPUTER ENGINEERING

Professor: Ruth E. Davis
Associate Professors: Hasan S. AlKhatib, Ronald L. Danielson, Mohammad Ali Ketabchi, Daniel W. Lewis *(Chair)*, Nam Ling
Assistant Professors: Qiang Li, Fuyau Lin, Weijia Shang
Clare Booth Luce Professor: Weijia Shang

The Computer Engineering degree features a balanced core program in which each student studies the engineering aspects of hardware and software as well as the underlying theory of computation. The Computer Engineering electives permit students to build on this core with varying emphasis, depending on their interests.

The Computer Engineering Program is supported by the facilities of the School of Engineering and the University's Academic Computing Center. The principal teaching computer system in the School of Engineering is a network of 60 HP 9000 high-end workstations, all in the Engineering Design Center—a well-maintained, sophisticated computing system available to undergraduate as well as graduate students. A large number of Sun and HP workstation systems and other equipment are available in the laboratories described below. The principal computing facilities supported by the Academic Computing Center include a DEC VAX/6610 and six personal computer laboratories with more than 200 IBM PCs.

Department Research and Teaching Labs

The *ASIC Testing Lab* (ATL) supports research in such topics as fault analysis on the device level, functional testability measures, partitioning HDL models for testability, and rapid prototyping using field programmable gate arrays (FPGAs).

The *Computer Systems and Parallel Processing Research Lab* supports research in systolic array design, interconnection networks, parallel operating systems, formal design verification, expert system development for architectural design, parallel software development methodology, application-oriented parallel algorithms, and VLSI design.

The *Digital Lab* is a teaching lab for design of digital systems, microprocessors, and digital signal processing. Facilities include HP 64000 development systems and TMS 320C25 and TMS 320C30 development systems.

The *Microelectronics Lab* is a teaching and research lab devoted to device and IC fabrication, device characterization, process and device simulation, parameter extraction, and VLSI design.

The *Signal and Image Processing Lab* is a teaching and research lab equipped with Sun 4 systems with RasterOps digitization and 24-bit color display and a Tektronics stereo display.

The *Software Engineering Lab* is a dedicated facility for the support of various research activities aimed at developing engineering techniques and tools that help produce and validate high-quality software. Specific research activities include formal specification and verification methods/tools, design framework for concurrent systems, Case architect, logic programming paradigms, and automatic reasoning.

The *Storage Technology Lab* supports research in recording head models and measurements, recording channel electronics, recording media measurements, and testing.

LOWER-DIVISION COURSES

4. Introduction to Programming

Structured algorithmic approach to problem solving using Pascal. Programming techniques such as top-down or stepwise refinement. Specification writing and the importance of documentation and self-documenting code. Credit not allowed for both COEN 4 and Math 10 or DISC 30. (4 units)

6. Introduction to Computing

Introduction to C++. Data types, variables, functions, parameters, control constructs, I/O. Use of simple C++ classes. Problem definition; design and implementation of algorithms, Elements of logic and logic expressions. Concept of recursion. Testing and debugging. Internet information access tools. Overview of computing as a discipline. (5 units)

6C. Introduction to Computing

Compressed version of COEN 6 taught in the graduate time format. (2 units)

7. Data Structures and Abstraction

Pointers and recursion. Data abstraction: abstract data types and object-oriented programming; building on existing components; relevant features of C++: classes and objects, inheritance, constructors and destructors. Simple data structures: stacks, queues, lists, binary trees, hashing, tables, graphs; implementation as abstract

data types. Internal sorting: review of selection, insertion and exchange sorts; quicksort, heapsort. Analysis of run-time behavior of algorithms; Big-O notation. Completion of at least four sizable programming assignments (400 lines). *Prerequisite: COEN 6 or equivalent knowledge of C, C++, Ada, or Pascal.* (4 units)

7C. Data Structures and Abstraction

Compressed version of COEN 7 taught in the graduate time format. *Prerequisite: COEN 6C or equivalent knowledge of C, C++, Ada, or Pascal.* (2 units)

11. Introduction to Digital Hardware

Evolution of digital computers. Overview of computer systems: CPU, memory, I/O interfaces, peripheral and mass storage devices, and networks. Logic operations, gates, and memory cells. Number systems: arithmetic and information representation; assembly and machine language programming: addressing techniques; instruction set: data movement, arithmetic and logic operations, machine control, branching and looping, stack operations, procedure calls and parameter passing. Exercises on debugging compiler-generated assembly code. *Prerequisite: COEN 6.* (4 units)

11C. Introduction to Digital Hardware

Compressed version of COEN 11 taught in the graduate time format. *Prerequisite: COEN 6.* (2 units)

19. Discrete Mathematics

Relations and operations on sets, orderings, elementary combinatorial analysis, recursion, algebraic structures, graphs. (Also listed as Math 51.) (4 units)

21. Introduction to Logic Design

Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing: setup and hold time; registers; counters. Implementation in standard cells, programmable logic, PLD, and FPGA. Use of Mentor Graphic Design Assistant in conjunction with XILINX. (Also listed as ELEN 21.) *Prerequisite: COEN 11 (may be taken concurrently); co-requisite: COEN 21L.* (4 units)

21C. Introduction to Logic Design

Compressed version of COEN 21 taught in the graduate time format. (Also listed as ELEN 21C.) *Prerequisite: COEN 11C (may be taken concurrently).* (2 units)

21L. Logic Design Lab

Laboratory for COEN 21. (Also listed as ELEN 21L.) *Co-requisite: COEN 21 or 21C.* (1 unit)

44. Applied Programming

Introduction to computer operating systems. Elements of computer programming in FORTRAN, including input/output, branching and loops, structured programming, programming for computational efficiency. Programming of elementary mathematical operations. Applications to engineering problems. *Co-requisites: MATH 21 and CENG 41.* (4 units)

70. Formal Specification and Advanced Data Structures

Specification, representation, implementation, and validation of advanced data structures. Object-oriented design and programming in a strongly typed language (Ada9X) with emphasis on reliable, reusable software. Formal specification of advanced data structures (e.g., graphs, sets, bags, tables, environments, "fancy" trees). Informal use of specifications to guide implementation and validation of programs. Values vs. objects and implications for implementation (copying vs. sharing, equality vs. identity, encapsulation). Guidelines and practice in designing for and with reuse. *Prerequisite: COEN 7.* (4 units)

UPPER-DIVISION COURSES

120. Microprocessor-based Design

Overview of microprocessor organization, hardware-software trade-offs. Survey of microprocessor architectures and assembly languages, LSI memory chips, memory section design, parallel and serial interfaces, interrupts, DMA channels, microcomputer development systems. (Also listed as ELEN 120.) *Prerequisites: COEN 11 and 21; co-requisite: COEN 120L.* (4 units)

120A. Microprocessor-based Design I

First half of COEN 120 taught in the graduate time format. (Also listed as ELEN 120A.) *Prerequisites: COEN 11C and 21C.* (2 units)

120B. Microprocessor-based Design II

Second half of COEN 120 taught in the graduate time format. (Also listed as ELEN 120B.) *Prerequisite: COEN 120A.* (2 units)

120L. Microprocessor Laboratory

Laboratory for COEN 120. (Also listed as ELEN 120L.) *Co-requisite: COEN 120.* (1 unit)

122. Computer Architecture

Overview of computer systems, CPU design, computer arithmetic, microprogramming techniques, memory hierarchies and management, input/output subsystem organization. Laboratory project consists of a design of a CPU. (Also listed as ELEN 122.) *Prerequisite: COEN 120.* (5 units)

127. Advanced Logic Design

Contemporary design of finite-state machines as system controllers using MSI, PLDs, or FPGA devices. Minimization techniques, performance analysis, and modular system design. Design and analysis of asynchronous systems. (Also listed as ELEN 127.) *Prerequisite: COEN 21; co-requisite: COEN 127L.* (4 units)

127C. Advanced Logic Design

Compressed version of COEN 127 taught in the graduate time format. (Also listed as ELEN 127C.) *Prerequisite: COEN 21C.* (2 units)

127L. Advanced Logic Design Lab

Laboratory for COEN 127 and 127C. Design, construction, and testing of controllers from verbal specs. Use of CAD design tools. (Also listed as ELEN 127L.) *Co-requisite: COEN 127 or 127C.* (1 unit)

129. Current Topics in Computer Engineering

Subjects of current interest. May be taken more than once if topics differ. (4 units)

133. Digital Signal Processing

Description of discrete signals and systems. Difference equations. Convolution summation. Z-transform, transfer function, system response, stability. Digital filter design and implementation. Introduction to C language implementations. Frequency domain analysis. Discrete Fourier transform and FFT. Laboratory for real-time processing. (Also listed as ELEN 133.) *Prerequisite: ELEN 110.* May be taken for graduate credit up to 12 units. (5 units)

134. Applications of Digital Signal Processing

Fast Fourier Transform (FFT), Radix-2 DIT and DIF algorithms. Fast convolution using FFT. Other FFT applications. Other algorithms for computing DFT. Design and analysis of digital filters. Applications of DSP in DTMF generation and decoding. Introduction to statistical signal processing. Applications of DSP in telecommunications. Includes Pulse Code Modulation (PCM), ADPCM, ADM, etc. Companding (μ-law and A-law), telephone networks, modems, etc. Applications of DSP in audio systems, compact disc technology, Dolby noise reduction, etc. Digital processing of speech. Intro-

duction to digital image processing. Introduction to adaptive signal processing/artificial neural networks. Hands-on laboratory for real-time DSP processing using TMS320C30, MATLAB, and Comdisco's SPW applications. (Also listed as ELEN 134.) *Prerequisite: COEN 133; knowledge of ELEN 141 is a plus.* (4 units).

145. Parallel Programming

Introduction to parallel processing. Typical multiprocessor architecture models (block level structures). Performance measurement and evaluation of parallel algorithms. Shared-memory parallel programming. Message-passing parallel programming. Data parallel programming. Parallelizing sequential code. Case studies on application algorithms. *Prerequisites: COEN 70 and either COEN 120 or 122.* (5 units)

146. Computer Networks

The ISO Open Systems Interconnect model. Data communications issues. Circuit and packet switching. Media access control protocols for shared channels: ALOHA and its derivatives, CSMA, CSMA/CD, token bus and ring, other protocols. Error detection and recovery. Sliding window techniques. Routing algorithms. Flow control. TCP, ISO TP4, RPC, Client/Server model. Network analysis techniques. Queuing systems, throughput-delay analysis. Laboratory consists of projects on software development of network protocols and applications as well as hardware network interfaces. *Prerequisites: COEN 7, COEN/ELEN 120, and AMTH 108.* (5 units)

*148. Computer Graphics Systems**

Interactive graphic systems. Graphics primitives, line and shape generation. Simple transforming and modeling. Efficiency analysis and modular design. Interactive input techniques. 3D transformations and viewing, hidden surface removal. Color graphics, animation, real-time display considerations. Parametric surface definition and introduction to shaded-surface algorithms. Offered in alternate years. *Prerequisites: Math 53 and COEN 7 or Math 61.* (5 units)

153. Digital Integrated Circuit Design

Analysis and design of digital MOS and bipolar integrated circuits. Based on first-order nonlinear device models, hand calculations and computer simulations (SPICE) used to design gates and SSIs. Circuit modeling considerations. Circuit performance evaluation with computer-aided circuit analysis. Design of MSIs from flowchart to layout. PLAs and finite state machines using array logic. Introduction to system design. (Also listed as ELEN 153.) *Prerequisites: ELEN 115 and COEN 21.* (5 units)

*171. Principles of Design and Implementation of Programming Languages**

High-level programming-language concepts and constructs. Costs of use and implementation of the constructs. Issues and trade-offs in the design and implementation of programming languages. Critical look at several modern high-level programming languages. Offered in alternate years. *Prerequisite: COEN 7 or Math 61.* (4 units)

*172. Structure and Interpretation of Computer Programs**

Techniques used to control complexity in the design of large software systems. Design of procedural and data abstractions; design of interfaces that enable composition of well-understood program pieces; invention of new, problem-specific languages for describing a design. Programs written and run in a dialect of LISP. Offered in alternate years. *Prerequisite: COEN 7 or Math 61.* (5 units)

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* Undergraduate course open to graduate students as space permits and only with permission of the dean of the School of Engineering.

*173. Logic Programming**

Application of logic to problem solving and programming; logic as a language for specifications, programs, databases, and queries; separation of logic and control aspects of programs; bottom-up reasoning (forward from assumptions to conclusions) versus top-down reasoning (backward from goals to subgoals); applied problem solving and programming; nondeterminism, concurrency, and invertibility in logic programs. Programs written and run in Prolog. Offered in alternate years. *Prerequisite: COEN 7 or Math 61.* (5 units)

174. Software Engineering

Object-oriented approach to software development. Software development life cycle. Project teams, documentation, and group dynamics. Software cost estimation. Formal specification. Data modeling, object modeling, and object-oriented analysis. Object-oriented programming and design. Software testing and quality assurance. CASE tools. *Prerequisite: COEN 70 or permission of instuctor.* (5 units)

*175. Introduction to Formal Language Theory and Compiler Construction**

Introduction to formal language concepts: regular expressions and context-free grammars. Compiler organization and construction. Lexical analysis and implementation of scanners. Top-down and bottom-up parsing and implementation of top-down parsers. An overview of symbol table arrangement, run-time memory allocation, intermediate forms, optimization, and code generation. *Prerequisite: COEN 7 or Math 61.* (5 units)

*176. Software Tools Design**

The design techniques for building good software tools. The concepts of filters, pipes, files, program arguments, and other facilities that make basic tools work well together. Learning by examination and modification of existing tools. Programming assignments are required in C language running under a UNIX environment. *Prerequisite: COEN 7 or Math 61.* (5 units)

*177. Operating Systems**

Introduction to organization of operating systems. Management of memory, processors, and other system resources; buffering: overlapping I/O and CPU processes, reducing rotational latency. Deadlock problems and avoidance. Process interaction and communication. Sharing and protection of processes and data. File systems: directory structure, file layout, data space management. Implementation considerations. *Prerequisite: COEN 7 or Math 61.* (5 units)

178. Introduction to Database Systems

File organization: B trees, B^+ trees, ISAM. Hierarchical, network, and relational data models. Database design techniques based on integrity constraints and normalization. Database languages; protection, backup, and recovery; concurrency control. *Prerequisite: COEN 7 or Math 61.* NCX† (5 units)

*179. Theory of Algorithms**

Preliminaries: measuring work done by algorithms. Nonnumerical algorithms: searching, sorting, graph spanning and traversal, string matching. Numerical topics: polynomial and matrix arithmetic. P and NP completeness. (Also listed as Math 163.) *Prerequisites: COEN 19 or Math 51 or 52, and COEN 7 or Math 61.* (4 units)

*180. Introduction to Information Storage**

Storage techniques and mass storage devices. Use of memory in computer systems. Design of semiconductor, magnetic and optical (disk drives), and magnetic tape memories. Storage controllers, computer interfaces, system software inter-

* Undergraduate course open to graduate students as space permits and only with permission of the dean of the School of Engineering. † Exempted from challenge

faces. Emphasis on current mass storage devices and interfaces: SCSI, IPI, ST506, ESDI. (Also listed as ELEN 180.) *Prerequisites: COEN 11 and 21; COEN 122 recommended.* (4 units)

188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work experience relating to their academic field of study and career objectives. Alternate or parallel periods of classroom study with periods of training in industry and government. Work includes overall report on assignment activities. P/NP grading. May be taken twice. May not be taken for graduate credit. Additional fees required. (2 units)

189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or a research project, etc., after completing the co-op assignment. Approval of department co-op adviser required. Letter grades based on content and presentation quality of report. May be taken twice. May not be taken for graduate credit. (2 units)

194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project adviser. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project report. *Prerequisite: English 182.* (2 units)

195. Design Project II

Continued design and construction of the project, system, or device. Initial draft of project report. *Prerequisite: COEN 194.* (2 units)

196. Design Project III

Continued design and construction of the project, system, or device. Final report. *Prerequisite: COEN 195.* (2 units)

199. Independent Study

Open to department scholars only. (1–6 units)

GRADUATE COURSES

Some graduate courses may not apply toward certain degree programs. As early as possible, preferably during the first quarter of study, students should investigate with their faculty adviser the program of study they wish to pursue.

200. Advanced Digital Design

Analysis and synthesis of combinational and sequential digital circuits with attention to static, dynamic, and essential hazards. Algorithmic techniques for logic minimization, state reductions, and state assignments. Decomposition of state machine, algorithmic state machine. Design for test concepts. (Also listed as ELEN 500.) *Prerequisite: COEN 127C.* (2 units)

201. Digital Signal Processing I

Description of discrete signals and systems. Z-transform. Convolution and transfer functions. System response and stability. Fourier transform. Sampling theorem. Digital filtering. State-space representations. (Also listed as ELEN 233.) *Prerequisite: ELEN 110.* (2 units)

202. Digital Signal Processing II

Continuation of COEN 201. Discrete Fourier transform. Digital filter design techniques. Fast Fourier transform. Quantization effects. Estimation. (Also listed as ELEN 234.) *Prerequisite: COEN 201.* (2 units)

203. VLSI Design I

Introduction to VLSI design methodology; hierarchical full custom design of CMOS digital circuits; design abstractions, lambda-based design rules, scaling, ratioed and switch logic, different logic structures; regular arrays, chip floor plans; timing models; distribution of global power, clock, and other buses. Use of various VLSI design CAD tools—schematic entry, place and route, and VHDL simulators. Examples of design of subsystems. (Also listed as ELEN 387.) *Prerequisites: COEN 200 and ELEN 115 or 250.* (2 units)

204. VLSI Design II

Continuation of design methodologies. Semicustom vs. custom designs. Hierarchical design of semicustom chips. ASIC designs. Programmable logic arrays, gate arrays, standard cells. Principles of placement and routing. Top-down design. Design verification. Examples of design of subsystems. (Also listed as ELEN 388.) *Prerequisite: COEN 203.* (2 units)

209. Switching Theory

Set theory. Boolean algebra. Two- and multilevel minimization techniques. Threshold logic. Sequential machines. Iterative networks. Pulse and fundamental mode operations. State reduction. Indistinguishability and compatibility. Decomposition (partitioning) of FSM. State assignments and the covering problem. Formal hardware verification. Reliability. Boolean difference. Reed–Mueller expansion. Linear feedback shift registers. Error correcting codes. (Also listed as ELEN 600.) *Prerequisite: COEN 127C.* (4 units)

210. Computer Architecture

Overview of computer structure and behavior. Register machine instructions and addressing: data types and storage organization, instruction format and sequencing, addressing modes, instruction sets. Processing unit. Instruction cycle. Pipelining. Control unit: hard-wired control unit, microprogrammed control unit. Microprogramming. Bit-slice devices. Input-output organization: interfacing, interrupts, direct memory access. Buses. Computer arithmetic: ALU design, arithmetic and branching conditions, multiplier design, floating-point numbers and operations. Memory: memory hierarchies, memory system considerations, memory interleaving, cache memories, virtual memories. RISC. *Prerequisites: COEN 127C and 11C.* (4 units)

217. Input-Output Devices

Card readers, line printers, disks, drums, magnetic tapes, keyboards, CRTs; analog-to-digital and digital-to-analog converters. (Also listed as ELEN 617.) *Prerequisite: COEN 210.* (2 units)

218. Input-Output Structures

Data transfers: synchronous and asynchronous; device selection and control; interfacing. Interrupt architectures; direct memory access. Channels, I/O processors. (Also listed as ELEN 618.) *Prerequisite: COEN 217.* (2 units)

233. Computer Networks

The ISO Open Systems interconnection model. Data communications issues. Circuits and packet switching. Media access control protocols for shared channels: ALOHA and its derivatives, CSMA, CSMA/CD, token bus ring, other protocols. Error detection and recovery. Sliding window techniques. Routing algorithms. Flow control. TCP, ISO TP4, RPC, Client/Server model. Network analysis techniques. Queuing systems, throughput delay analysis. *Prerequisites: COEN 7C, COEN/ELEN 120, and AMTH 210.* (4 units)

234. Unix Network Programming

Overview of Unix networking tools. Detail of the different Internetwork-Process Communication (IPC) facilities under Unix to develop distributed applications. IPC user interfaces including: pipes, shared memory, message queues, semaphores, sockets, system V Transport Layer Interface (TLI), and Remote Procedure Calls (RPC). Network protocols supported under the Unix environment including: TCP/IP, XNS, SNA, and NetBIOS. *Prerequisites: COEN 233, 276, and 284.* (2 units)

251. Data Structures and Algorithms

Algorithms analysis. ADT for lists, stacks, queues, trees, and sets. Hashing, searching, and sorting. Graph algorithms. Memory management. Algorithm design techniques. Measures of complexity. Space and time hierarchies. NP-completeness. Reducibility between problems. Intractable problems. *Prerequisite: COEN 7C.* (4 units)

255. Programming Languages

High-level programming language concepts and constructs. Costs of use and implementation of the constructs. Issues and trade-offs in the design and implementation of programming languages. Critical look at several modern high-level programming languages. *Prerequisite: COEN 7C.* (2 units)

257. Formal Languages and Introduction to Compiler Construction

Regular expressions. Regular languages and their properties. Finite state automata and their conversion and minimization. Lexical analysis and their implementations. Chomsky's hierarchy. Context-free languages and their properties. Push-down automata and recognition of formal languages. Top-down and bottom-up parsers and their implementation. *Prerequisite: COEN 7C.* (4 units)

258. Semantic Analysis and Code Generation

Implementation of bottom-up parsers. Attributed grammar. Semantic analysis. Symbol table organization. Run-time memory allocation. Code generation. *Prerequisite: COEN 257.* (2 units)

260. Truth, Deduction, and Computation

Introduction to mathematical logic and semantics of languages for the computer scientist. Investigation of the relationships among what is true, what can be proved, and what can be computed in the formal systems of propositional logic, predicate calculus, elementary number theory, and the lambda calculus. (3 units)

261. Structure and Interpretation of Computer Programs

Programming in a modern, high-level, functional programming language (i.e., one with functions, or procedures, as first-class objects and facilities for abstract data types). Techniques used to control complexity in the design of large software systems. Design of procedural and data abstractions; design of interfaces that enable composition of well-understood program pieces; invention of new, problem-specific languages for describing a design. Programs written and run in a dialect of LISP. *Prerequisite: COEN 251.* (2 units)

270. Automata and Computability Theory

Finite automata. Push-down automata and context-free grammar. Turing machines. Chomsky hierarchy. Decidability. Numeric computation. Recursive functions (theory). Feasible and infeasible problems. Computational complexity. *Prerequisite: COEN 251.* (4 units)

276. Software Tools Design

Design techniques for building good software tools. Concepts of filters, pipes, files, program arguments, and other facilities that make basic tools work well together. Learning by examining and modi-

fying existing tools. Programming assignments are required in C language running under a UNIX environment. *Prerequisites: COEN 251 and C language.* (4 units)

277. Graphical User Interface Design and Programming

User interface metaphors. End user task analysis. Basic user interface concepts. Software architecture for graphical user interface applications. Object-oriented approach design. Event-driven control flow. Term project. *Prerequisite: COEN 276 or familiarity with X11/Motif or MS-Windows programming.* (2 units)

280. Database Systems

Data models. Relational databases. Database design (normalization and decomposition). Data definition and manipulation languages (related algebra and calculus). Architecture of database management systems. Transaction management. Concurrency control. Security, distribution, and query optimization. *Prerequisite: COEN 251.* (4 units)

283. Operating Systems

Introduction to operating systems. Process management and scheduling. Concurrency control. Synchronization problem. Critical section problem. Language constructs for concurrent programming. Deadlock handling. Memory management. File systems. Performance. Distributed operating systems. *Prerequisite: COEN 7C.* (4 units)

284. Operating Systems Case Study

Case study of a large multiuser operating system: implementation of different operating system components. Operating system for network and distributed processing systems: naming, resource allocation, synchronization, fault detection and recovery, deadlock. *Prerequisite: COEN 283.* (2 units)

285. Software Engineering

Systematic approaches to software design, project management, implementation, documentation, and maintenance. Software design methodologies: SA/SD, OOA/OOD. Software quality assurance; testing. Reverse engineering and re-engineering. CASE. Term project. *Prerequisite: COEN 251.* (4 units)

286. Software Quality Assurance & Testing

Social factors. Configuration management. Software complexity measures. Functional and structuring testing. Test coverage. Mutation testing. Trend analysis. Software reliability. Estimating software quality. Testing OOPs. Confidence in the software. Software quality control and process analysis. Managerial aspects. *Prerequisite: COEN 285.* (2 units)

287. Software Development Process Management

Development process and issues. Development process handbook. Configuration management. Planting. P-process description, deliverables, and procedures. Process monitoring. Managerial issues on product development and maintenance. Software testing. Adopting new technologies. *Prerequisite: COEN 285.* (2 units)

290. Computer Graphics I

Raster and vector graphics image generation and representation. Graphics primitives, line and shape generation. Scan conversion anti-aliasing algorithms. Simple transformation, windowing and hierarchical modeling. Interactive input techniques. 3D transformations and viewing, hidden surface removal. Introduction to surface definition with B-spline and Bezier techniques. Surface display with color graphics. *Prerequisites: COEN 7C and AMTH 245.* (2 units)

296. Topics in Computer Engineering

Various subjects of current interest. May be taken more than once if topics differ. (2 units)

301. Logic Synthesis

Synthesis strategy. Hardware description language and its applications in synthesis. Cost elimination. Multilevel logic synthesis and optimization. Synthesis methods and systems. Module generation. Timing considerations. Area vs. speed trade-offs. Design simulation and verification. Heuristic techniques. CAD tools. (Also listed as ELEN 601.) *Prerequisites: COEN 210 and COEN 200 or 209.* (2 units)

303. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Different views of HDL—structural, register transfer, and behavioral. Simulation and synthesis of systems descriptions. (Also listed as ELEN 603.) *Prerequisite: COEN 200.* (2 units)

304. Semicustom Design with Programmable Devices

Digital circuit design methodologies. Semicustom implementations. Programmable logic devices—classification, technology, and utilization. Software tools—synthesis, placement, and routing. Design verification and testing. (Also listed as ELEN 604.) *Prerequisite: COEN 200.* (2 units)

305. Silicon Compilation

Techniques used for computer-aided design of VLSI circuits. Layout compaction, procedural design, and module generators. Algorithms for placement, floor planning, and routing. PLA and gate-matrix compaction. Heuristic, deterministic, and probabilistic algorithm design and analysis for VLSI. Logic, structural and behavioral synthesis, and optimization. Principles and examples of silicon compilers. Expert systems for silicon compilation. (Also listed as ELEN 389.) *Prerequisites: COEN 204 and 251.* (2 units)

306. Integrated Circuits Testing

Fundamental principles of testing digital circuits. Mapping of physical defects into failure modes and fault models. Dependence of the fault models on the technology. Parametric and Boolean testing. Deterministic and probabilistic techniques for test pattern generation. Techniques for testing memories and microprocessors. Use of computer-aided testing (CAT) tools. (Also listed as ELEN 606.) *Prerequisites: ELEN 250 and COEN 200 or equivalent courses.* (2 units)

307. Digital Computer Arithmetic

Fixed-point and floating-point number representation and arithmetic. High-speed addition and subtraction algorithms and architectures. Multiplication and division algorithms and architectures. Decimal arithmetic. Serial vs. parallel arithmetic circuits. Residue number arithmetic. Advanced arithmetic processing units. High-speed number crunchers. Arithmetic codes for error detection. VLSI perspective and reliability issues. *Prerequisite: COEN 210.* (2 units)

308. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. Ad hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST) techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. (Also listed as ELEN 608.) *Prerequisites: COEN 200 and either ELEN 115 or 250.* (2 units)

309. Fault-Tolerant Digital Systems

Hardware and software techniques for meeting stringent reliability demands with digital systems. Hardware redundancy techniques. Concurrent checking techniques. Error-detecting and error-correcting codes. Other related topics of interest. (Also listed as ELEN 609.) *Prerequisite: COEN 210.* (2 units)

310. Digital Testing with ATE

Design-, manufacturing-, and packaging-induced faults identified. Static and dy-

namic electrical tests under normal and stressed conditions. Architecture of different automatic test equipment (ATE) and their corresponding test programming software environments. Test-result logging for statistical process control. (Also listed as ELEN 610.) *Prerequisites: COEN 200 and ELEN 250.* (2 units)

311. Comparative Computer Architecture

Advanced topics in computer system design. Comparative analysis of various computer architectures. Survey of some novel architectures. Future trends in computer architectures. *Prerequisite: COEN 210.* (2 units)

312. Parallel Computation Systems I

Introduction to concepts and implementation techniques of parallel processing. Classifications. Parallel computational models and algorithms. Performance issues and speed-up techniques. Interconnection networks. Vector processors. SIMD parallel architectures. Systolic arrays. Shared-memory and message-passing MIMD parallel architectures. Software issues for parallel systems. *Prerequisites: COEN 210 and 7C.* (2 units)

313. Computer Architecture III

Advanced systems architectures; von Neumann vs. non–von Neumann architectures. Overview of different computing paradigms. Object-oriented architectures. RISC vs. CISC. Capability addressing. Dataflow machines. Symbolic vs. numeric architectures. Artificial neural networks. Learning machines. *Prerequisite: COEN 210.* (2 units)

314. Parallel Computation Systems II

MIMD paradigm-based parallel architectures. SIMD/MIMD hybrids. Dataflow architectures. Reduction architectures. Wavefront arrays. VLIW architectures. Other unconventional high-speed systems. Parallel algorithms. Introduction to parallel programming languages, parallelizing compilers, and parallel operating systems. Formal techniques in parallel system design. Industrial examples. *Prerequisite: COEN 312.* (2 units)

315. Computer Performance Evaluation

Measurement, simulation, and analytic determination of computer systems performance. Work load characterization. Bottleneck analysis tuning. *Prerequisites: COEN 210 and AMTH 106 and 211.* (2 units)

316. Application-Specific Array Processors

Introduction to algorithm-based application-specific designs. Systolic arrays. Wavefront arrays. SIMD and MIMD applications-specific designs. Algorithms for systolic arrays. Mapping techniques. Matching and partitioning. Formal design specifications and verifications. Systolic temporal arithmetic. System organization: host, control, interfacing, processor arrays, interconnection networks. Industrial systems. Software for array processors. Applications of systolic arrays to DSP, image processing, neural networks, etc. (Also listed as ELEN 616.) *Prerequisite: COEN 210.* (2 units)

319. Parallel Programming

Software and application issues of parallel systems. Mapping applications to parallel architectures. Problem partitioning. Parallel algorithms. Parallel programs. Parallel compiler design. Hardware-independent parallel programming. Parallel operating systems. Case studies of typical problem solutions and algorithms of parallel systems. *Prerequisite: COEN 314.* (2 units)

322. Advanced Microprocessor Architecture

A survey of advanced microprocessors: Intel 80X86; Motorola 6800; RISC processors; SPARC; MIPS. Special and advanced features in microprocessor architectures. *Prerequisite: COEN 120B.* (2 units)

323. Special-Purpose Microprocessors

Different topics on special-purpose microprocessors, signal processing architectures, arithmetic processors, communication controllers, graphics controllers, and other advanced topics. *Prerequisite: COEN 120B.* (2 units)

330. Design and Analysis of Computer Networks

History of computer networks. The ISO-OSI model. Graph theory algorithms for the design of computer networks. Introduction to queueing theory techniques for the calculation of network delays. Network backbone design. Local access design. Basic data communication concepts. Brief introduction to sample protocols for each ISO-OSI layer. Protocol modeling and verification. *Prerequisites: COEN 233 and AMTH 106 and 211.* (2 units)

332. Local Area Networks

Overview of multiprocessor systems and computer busing structures. Shared-memory systems. Packet-Radio networks. Baseband Local Area Networks; CSMA, CSMA/CD, token rings and buses, slotted rings, tokenless rings. Broadband Local Area Networks. Current issues on the implementations and applications of Local Area Networks. *Prerequisite: COEN 330.* (2 units)

334. Advanced Unix Network Programming

Applications of Unix IPC facilities including: File Transfer Protocol (FTP), line printer spoolers, remote command execution, remote log in. IPC performance analysis. Overview of OSF Distributed Computing Environment (DCE). *Prerequisite: COEN 234.* (2 units)

338. High-Performance Data Compression

Requirements for multimedia applications. Digital image compression. Color coding and compression. Digital video compression. Digital audio compression. Text compression. Entropy coding. Predictive coding. Motion compensation. 2-D discrete cosine transform. Vector quantization. Discrete wavelet transform. Fractal methods. Lempel–Ziv method. Fast DCTs and other high-speed compression algorithms. Distributed arithmetic techniques. Parallel processing techniques for compression. Compression standards such as JPEG, MPEG1, MPEG2, and H.261. Image and video compression architectures. Industrial examples. Applications such as multimedia computing and video conferencing. *Prerequisite: COEN 210.* (4 units)

340. Digital Image Processing I

Digital image representation and acquisition; Fourier, Cosine, Walsh, and wavelet transforms; linear and nonlinear filtering; image enhancement; morphological filtering. (Also listed as ELEN 640.) *Prerequisite: COEN 202.* (2 units)

343. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domain; matrix representations; blind deconvolution; reconstructions from incomplete data; image segmentation methods. (Also listed as ELEN 643.) *Prerequisite: COEN 340.* (2 units)

344. Computer Vision I

Introduction to image understanding, sensor models, image enhancement and restoration for vision, stereo vision, pattern recognition, segmentation, high-level scene interpretation, human vision. (Also listed as ELEN 644.) Offered in alternate years. *Prerequisites: ELEN 233 or 640 and ELEN 235 or AMTH 211.* (2 units)

345. Computer Vision II

Current topics in image understanding research. 3-D vision. Regularization. Energy function misinformation. Robust techniques. Neural networks. Symbolic processing. (Also listed as ELEN 645.) Offered in alternate years. *Prerequisite: COEN 344.* (2 units)

357. Code Generation and Optimization

Optimization philosophies and objectives. Basic blocks and their DAG representations. Loop optimizations: code motion and strength reduction. Dataflow analysis: live variables, available and very busy expressions. Global optimizations: subexpression elimination, constant folding, and code propagation. Peephole optimizations. *Prerequisite: COEN 258.* (2 units)

358. Introduction to Parallelizing Compilers

Introduction to parallelizing compiler techniques. Automatic restructuring. Loop transformation. Dependence analysis. Vectorization. Partitioning and scheduling. Data alignment. Data distribution. Algorithm mapping. Parallel code generation. *Prerequisite: COEN 312 or permission of instructor.* (4 units)

362. Logic Programming

Application of logic to problem solving and programming; logic as a language for specifications, programs, databases, and queries; separation of the logic and control aspects of programs; bottom-up vs. top-down reasoning applied to problem solving and programming; nondeterminism, concurrency, and invertibility in logic programs. Programs written in Prolog and run on the computer. *Prerequisite: COEN 260.* (2 units)

364. Denotational Semantics I

Complete partially ordered sets, approximations and limits, least fixed points and continuous functions, and the lambda calculus as the mathematical background for discussion of techniques used to describe languages: semantic functions, environments, continuations, stores. *Prerequisites: COEN 260 and 261 and AMTH 241.* (2 units)

365. Denotational Semantics II

Continuation of 364. *Prerequisite: COEN 364.* (2 units)

367. Artificial Intelligence I

Artificial intelligence viewed as knowledge engineering. Historical perspective. Problems of representation: AI as a problem in language definition and implementation. LISP, formal reasoning, natural language, vision and robotics, research techniques. *Prerequisites: COEN 260 and 261; COEN 362 recommended.* (2 units)

368. Artificial Intelligence II

Continuation of COEN 367. *Prerequisite: COEN 367.* (2 units)

369. Planning and Problem Solving

Survey of available techniques and tools for building planners, distinctions between problem solvers and simple planners, and use of planners in AI systems. Latest published research and pragmatic results. Emphasis on understanding and presenting the planning/problem-solving literature. Topics include temporal logics, reasoning about causality, action representations, planning algorithms, reactive systems, and world-modeling. *Prerequisite: COEN 368.* (2 units)

377. Expert Systems I

Overview of tools and applications of expert systems as well as the theoretical issues—what is knowledge, can it be articulated, and how to represent it. Stages in the construction of expert systems: problem selection, knowledge acquisition, development of knowledge bases, choice of reasoning methods, life cycle of expert system projects. Basic knowledge representation techniques (rules, frames, objects) and reasoning methods (forward-chaining, backward-chaining, neuristic classification, constraint reasoning, and related search techniques). *Prerequisite: COEN 367.* (2 units)

378. Expert Systems II

Completion of a knowledge-engineering project and participation in discussions involving the major topics. Readings include relevant research papers. *Prerequisite: COEN 377.* (2 units)

382. Database Management Systems for Advanced Data-Intensive Applications

Data management requirements of advanced data-intensive applications such as computer-aided design, computer-aided software engineering, and expert systems. Approaches to meeting the requirements. Fundamentals of object-oriented database management systems. Examples of object-oriented database management systems and their use in advanced data-intensive applications. *Prerequisites: COEN 255 and 280.* (2 units)

384. Advanced Operating Systems

Advanced process synchronization and deadlock handling. Distributed operating system issues: logic clock, mutual exclusion, deadlock handling, resource management, scheduling. Microkernel-based systems and multiprocessor operating systems. Security and fault tolerance. Real-time systems. *Prerequisites: COEN 283 and 284.* (2 units)

385. Formal Methods in Software Engineering

Specification, verification, validation. Notations and the models they support. Classes of specification models: algebraic, state machine, model theoretic. Developing a verification and validation strategy fitting the model of the application. Appropriate use of formal methods: requirements, design, implementation, testing, maintenance. Case studies. *Prerequisite: COEN 260 or other courses in predicate logic.* (2 units)

386. Software Architecture

Understanding and evaluating software systems from an architectural perspective. Classification, analysis, tools, and domain-specific architectures. Provides intellectual building blocks for designing new systems using well-understood architectural paradigms. Examples of actual system architectures that can serve as models for new designs. *Prerequisite: COEN 385.* (2 units)

387. Software Analysis, Maintenance, and Reverse Engineering

Identification, classification, and analysis of software maintenance processes. Techniques, information, and tools required to support these processes. Architecture and development of software analysis and maintenance systems. Survey of state-of-the-art technology in software analysis, maintenance, and reverse engineering. *Prerequisite: COEN 7C or equivalent.* (2 units)

388. Principles of Computer-Aided Engineering Design

Introduction to computer-aided design. Discussion of computer-aided design tools and systems. Algorithms for performing computer-aided design tasks and implementation of those algorithms. Emphasis may be on VLSI design, system design, or software design in different quarters. *Prerequisite: COEN 251.* (2 units)

389. Design and Verification Methodology

Design paradigms. Formal techniques on analysis, synthesis, specification, and verification of hardware and software systems. Program and architecture derivation and proof of correctness. Stepwise refinement. Formal transformation. Formal verification. Formal logic, calculus, and theorem provers for automatic design and verification. High-order and temporal logics. Connection among data structures, refinement process, and program control. Transforming algorithms to parallel architectures. Specification languages. Timing verifications. Case study. Techniques applicable to both hardware and software designs. *Prerequisites: COEN 210 and 251.* (2 units)

391. Computer Graphics II

Three-dimensional graphics: surface and solid modeling with polygon mesh, Bezier, and B-spline techniques. Ray tracing algorithms. Illumination models and

color graphics. Generation of realistic scenes. Fractal methods. *Prerequisite: COEN 290.* (2 units)

392. Computer Graphics III

Graphics for animation and real-time image generation. Realism, texture modeling, and use of image data with graphics. Visualization techniques. (Offered in alternate years.) *Prerequisite: COEN 290.* (2 units)

395. Discrete Event Simulation

Introduction to modeling techniques of discrete event systems. Discrete event simulation through event scheduling and process interaction. Overview of SIMULA as a simulation tool. Designing simulation experiments. Probability distribution models. Variance-reduction techniques. Determination of Stopping Rules. (Also listed as DISC 206.) *Prerequisites: COEN 7C and AMTH 211.* (3 units)

396. Advanced Topics in Computer Engineering

Various subjects of current interest. May be taken more than once if topics differ. (2 units)

397. Research Seminar in Digital Systems

Advanced topics in digital systems—design and test. Themes vary yearly (e.g., memory devices, effect of GaAs on performance and reliability, missing technologies, etc.). Students are expected to investigate current research and practices and give oral presentations. (Also listed as ELEN 697.) *Prerequisite: permission of instructor.* (2 units)

400. Computer Engineering Graduate Seminars

Regularly scheduled seminars on topics of current interest in the fields of electrical engineering and computer engineering. Consult department office for detailed information. P/NP grading. (Also listed as ELEN 200.) (1–2 units)

481. Software Engineering Project

A Capstone Course in which the student applies software engineering concepts and skills to a large software engineering project conducted in a team environment. Project report. With adviser approval, may be completed through a cooperative work assignment in local industry. (2 units)

497. Master's Thesis Research

By arrangement. (1–9 units)

498. Ph.D. Thesis Research

By arrangement. A nominal number of 45 units is expected toward Ph.D. degree. (1–15 units)

499. Independent Study

Special problems and/or research. By arrangement. (1–6 units)

DEPARTMENT OF ELECTRICAL ENGINEERING

Professors Emeriti: Shu-Park Chan, Henry P. Nettesheim
Professors: Timothy J. Healy *(Chair)*, Samiha Mourad, Dragoslav D. Siljak, Sally L. Wood, Cary Y. Yang, Raymond B. Yarbrough
Associate Professors: Jack A. Peterson, M. Mahmudur Rahman
Assistant Professors: Tokunbo Ogunfunmi, Aleksandar Zecevic
Adjunct Professor and Director, Institute for Information Storage Technology: Albert S. Hoagland
Senior Lecturer: Donald P. Leach
Thomas J. Bannan Professor: Timothy J. Healy
Benjamin and Mae Swig Professor: Dragoslav D. Siljak

Electrical engineering includes the design, construction, and operation of electrical components, circuits, and systems. Electrical engineers are concerned with all phases of the electrical transmission of information such as in radio, television, satellite communications, fiber optics, electric power, and telephone systems. Data processing and data storage equipment and computers used by business, industry, and government are included in their major area of interest.

The Electrical Engineering Program is supported by the facilities of the University's Academic Computing Center, as well as six major teaching and research laboratories and three additional laboratories used only for teaching. The principal computers for the University's academic functions include a Digital Equipment Corporation VAX-6610, and six personal computer laboratories with more than 200 IBM PCs. In addition, the School of Engineering has a large number of workstation systems from Hewlett-Packard, IBM, Sun, and DEC. The major teaching system, one of the most sophisticated and modern undergraduate teaching facilities in the world, is a network of 60 HP 9000 high-end workstations.

The three teaching laboratories cover the fields of electric circuits, electronic circuits, and digital circuits. The following research and teaching laboratories are used in the graduate program:

ASIC Testing Laboratory (ATL) Supports research in such topics as fault analysis on the device level, functional testability measures, partitioning HDL models for testability, and rapid prototyping using field programmable gate arrays (FPGAs).

Digital Laboratory Digital systems. Microprocessors. HP 64000 Microprocessor Development Systems. Digital signal processing. TMS 320C25 and TMS 320C30 development systems.

Microelectronics Laboratory Device and IC fabrication. Device characterization. Process and device simulation. Parameter extraction. VLSI design.

Microwaves and Communications Laboratory Spectral and network analysis. HP 8753 Vector Network Analyzers. Touchstone, HP-MDS, and other CAD/CAE software on IBM AT and HP 360. Device design, construction, and measurement.

Intelligent Control Laboratory IBM 7545 robots, Teachmover Microbots, HP 9000 workstations, servosystems, electromechanical measurement devices.

Signal and Image Processing Laboratory Sun 4 systems with RasterOps digitization and 24-bit color display. Tektronics stereo display.

Storage Technology Laboratory Recording head models and measurements. Recording channel electronics. Recording media measurements and testing. The read/write process.

LOWER-DIVISION COURSES

10. Introduction to Electrical Engineering

Introduction to fundamental concepts of electrical engineering: communications, control, computers, and electronics. Basic concepts presented in the context of current practice, such as digital audio, television, robotics, and integrated circuits. Includes interactive demonstrations and projects. (4 units)

21. Introduction to Logic Design

Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flop-flops; timing: setup and hold time; registers; counters. Implementation in standard cells, programmable logic, PLD, and FPGA. Use of Mentor Graphic Design Assistant in conjunction with XILINX. (Also listed as COEN 21.) *Prerequisite: COEN 11 (may be taken concurrently); co-requisite: ELEN 21L.* (4 units)

21C. Introduction to Logic Design

Compressed version of ELEN 21 taught in the graduate time format. (Also listed as COEN 21C.) *Prerequisite: COEN 11C (may be taken concurrently).* (2 units)

21L. Logic Design Lab

Laboratory for ELEN 21. (Also listed as COEN 21L.) *Co-requisite: ELEN 21 or 21C.* (1 unit)

50. Electric Circuits I

Physical basis and methematical models of circuit components and energy sources. Circuit theorems and methods of analysis are applied to DC and AC circuits. Labo-

UPPER-DIVISION COURSES

100. Electric Circuits II

Continuation of ELEN 50, including sinusoidal steady state and phasors, transformers, three-phase circuits, resonance, Laplace analysis, transfer functions. Fourier series. Laboratory. *Prerequisite: ELEN 50 or Physics 70.* (5 units)

104. Electromagnetics I

Static electric and magnetic fields and their sources and effects, including potential theory and the laws of Coulomb, Lorentz, Faraday, and Gauss. Introduction to vector analysis and differential operators. Dielectric and magnetic materials, capacitance and inductance, energy in magnetic and electric fields, solutions to the Poisson equation. *Prerequisites: Physics 6 and ELEN 50; co-requisite: ELEN 100.* (4 units)

105. Electromagnetics II

Time harmonic electromagnetic fields. Introduction to complex vector operations. Maxwell's equations and the laws of Faraday and Gauss. Conservation of charge and power, Poynting vectors. Helmholtz wave equation, wave propagation. Boundary conditions and wave reflection and propagation. Snell's law. Transmission line theory, introduction to the Smith chart. Waveguides and radiation. *Prerequisite: ELEN 104 or Physics 111.* (4 units)

107. Information Storage Technology

Emphasis on magnetic data storage; technology, devices, and systems. Overview of alternative technologies. The recording process and electromechanical design trade-offs of moving media storage systems. Challenges faced in securing continuing cost/performance advances in terms of cost/bit, access time, transfer data rate, and reliability. *Prerequisites: ELEN 104 or Physics 111, and ELEN 180.* May be taken for graduate credit up to 12 units. (4 units)

109. Applications of Electromagnetics

Review of Maxwell's equations. Circuit elements and circuits. Nonideal transmission lines. Boundary value problems. Conformal transforms. Waveguides. Resonant cavities. Microwave networks and materials. *Prerequisite: ELEN 105.* (4 units)

110. Linear Systems

Signals and system modeling. Laplace transform. Transfer function. Convolution. Discrete systems and Z-transform. Frequency analysis. Fourier series and transform. Filtering. Problem sessions. *Prerequisite: ELEN 100.* (5 units)

111. Analysis of Linear Systems and Applications

Review of matrix/linear algebra. Matrix foundation of system equations. Introduction to state-space description of systems. Frequency response techniques. Discrete systems and Z-transform techniques. Discrete Fourier Transform (DFT). Fast Fourier Transform (FFT). Introduction to MATLAB as a tool. Problem solving with MATLAB with examples. Numerical solution of differential equations. Numerical solution of difference equations. Writing structured programming using C/MATLAB. *Prerequisite: ELEN 110.* (4 units)

112. Modern Network Synthesis and Design

Approximation, synthesis of passive one-port and two-port networks, linear operational amplifiers and active R-C synthesis. Nonlinear operational amplifiers: phase-locked loops, waveform generation. Design project. *Prerequisite: ELEN 110.* May be taken for graduate credit up to 12 units. (5 units)

114. Introduction to Topological Analysis

Introduction to topological analysis of linear networks and systems. Elementary network topology; planarity and duality; topological analysis of linear one-ports and two-ports; symbolic functions and sensitivity analysis; computer-aided topological analysis and optimization; introduction to topological synthesis and design. *Prerequisite: ELEN 100.* (4 units)

115. Electronic Circuits I

The p-n junction diodes, bipolar junction transistors (BJT), junction field effect transistors (JFET), metal-oxide-silicon field effect transistors (MOSFET). Study of physical behavior, modes of operation, terminal characteristics, and equivalent circuit models for each of these devices. Emphasis on using simplified models to perform rapid circuit analysis for a number of basic circuit configurations. Primary objectives: knowledge of the single transistor switch and the single transistor analog amplifier. *Prerequisite: ELEN 50.* (5 units)

116. Electronic Circuits II

Analog amplifiers. Differential amplifier using BJTs and MOSFETs. Amplifier output stages and integrated circuit (IC) power amplifiers. Detailed consideration of amplifier frequency response and wide-band amplifier configurations. Practical circuit applications using negative feedback to enhance amplifier performances. Topics combined in the study of multi-stage (multitransistor) amplifier circuits. *Prerequisite: ELEN 115.* (5 units)

117. Electronic Circuits III

Introduction to BJT and MOSFET analog ICs. Detailed study of the popular 741 Operational Amplifier (OA), digital circuits and systems, as well as VLSI circuit design. Numerous specialized circuits including tuned amplifiers, oscillators and precision circuits using OAs. Detailed consideration of the internal operation of BJT and MOS digital circuits. *Prerequisite: ELEN 116.* (5 units)

119. Current Topics in Electrical Engineering

Subjects of current interest. May be taken more than once if topics differ. (4 units)

120. Microprocessor-based Design

Overview of microprocessor organization, hardware-software trade-offs. Survey of microprocessor architectures and assembly languages, LSI memory chips, memory section design, parallel and serial interfaces, interrupts, DMA channels, microcomputer development systems. (Also listed as COEN 120.) *Prerequisites: COEN 11 and ELEN 21; co-requisite: ELEN 120L.* (4 units)

120A. Microprocessor-based Design I

First half of ELEN 120 taught in the graduate time format. (Also listed as COEN 120A.) *Prerequisites: COEN 11C and ELEN 21C.* (2 units)

120B. Microprocessor-based Design II

Second half of ELEN 120 taught in the graduate time format. (Also listed as COEN 120B.) *Prerequisite: ELEN 120A.* (2 units)

120L. Microprocessor Laboratory

Laboratory for ELEN 120. (Also listed as COEN 120L.) *Co-requisite: ELEN 120.* (1 unit)

122. Computer Architecture

Overview of computer systems, computer arithmetic, microprogramming techniques, memory hierarchies and management, input/output subsystem organization. Laboratory project consists of a design of a CPU. (Also listed as COEN 122.) *Prerequisite: ELEN 120.* May be taken for graduate credit up to 12 units. (5 units)

127. Advanced Logic Design

Contemporary design of finite-state machines as system controllers using MSI, PLDs, or FPGA devices. Minimization techniques, performance analysis, and modular system design. Design and analysis of asynchronous systems. (Also listed as COEN 127.) *Prerequisite: ELEN 21; co-requisite: ELEN 127L.* (4 units)

127C. Advanced Logic Design

Shortened version of ELEN 127 taught in the graduate time format. (Also listed as COEN 127C.) *Prerequisite: ELEN 21C.* (2 units)

130. System Control and Design

Descriptions of control systems. The principle of feedback. Performance specifications: transient and steady-state response. Stability: Routh-Hurwitz test. Design methods. Root-locus. Frequency response techniques of Nyquist, Bode, and Nichols. Lead and lag controller design. Laboratory. *Prerequisite: ELEN 110.* May be taken for graduate credit up to 12 units. (5 units)

131. Introduction to Robotics

Overview of robotics: control, AI, and computer vision. Components and structure of robots. Kinematics and dynamics of robot manipulators. Servo-control design, PID control. Trajectory planning, obstacle avoidance. Sensing and vision. Robot intelligence and task planning. Laboratory. *Prerequisite: ELEN 110.* (5 units)

133. Digital Signal Processing

Description of discrete signals and systems. Difference equations. Convolution summation. Z-transform, transfer function, system response, stability. Digital filter design and implementation. Introduction to C language implementations. Frequency domain analysis. Discrete Fourier transform and FFT. Laboratory for real-time processing. (Also listed as COEN 133.) *Prerequisite: ELEN 110.* May be taken for graduate credit up to 12 units. (5 units)

134. Applications of Digital Signal Processing

Fast Fourier Transform (FFT), Radix-2 DIT and DIF algorithms. Fast convolution using FFT. Other FFT applications. Other algorithms for computing DFT. Design and analysis of digital filters. Applications of DSP in DTMF generation and decoding. Introduction to statistical signal processing. Applications of DSP in telecommunications. Includes Pulse Code Modulation (PCM), ADPCM, ADM, etc. Companding (μ-law and A-law), telephone networks, modems, etc. Applications of DSP in audio systems, compact disc technology, Dolby noise reduction, etc. Digital processing of speech. Introduction to digital image processing. Introduction to adaptive signal processing/artificial neural networks. Hands-on laboratory for real-time DSP processing using TMS320C30, MATLAB, and Comdisco's SPW applications. (Also listed as COEN 134.) *Prerequisite: ELEN 133; knowledge of ELEN 141 is a plus.* (4 units)

139. Special Topics in Signals and Systems

Subjects of current interest. May be taken more than once if topics differ. (4 units)

141. Communication Systems

Signal description; Fourier transforms; filtering; noise description; linear, exponential, and pulse modulation and demodulation. Laboratory. *Prerequisite: ELEN 110.* May be taken for graduate credit up to 12 units. (5 units)

144. RF and Microwave Components

Passive and active electrical components used in radio frequency and microwave circuits. Emphasis on fundamental characterization of components. Parasitics, models, and measurements. Resistors, inductors, capacitors, transmission lines, diodes, transistors. *Prerequisite: ELEN 105.* May be taken for graduate credit up to 12 units. (5 units)

145. RF and Microwave Circuits

Design, construction, and testing of typical RF and microwave circuits including filters, amplifiers, and oscillators. System measurements. *Prerequisite: ELEN 144.* May be taken for graduate credit up to 12 units. (5 units)

151. Semiconductor Devices I

Materials properties, crystal structure, and band structure of semiconductors. Carrier statistics and transport; p-n junction statics, I-V characteristics, equivalent circuits, and switching response. Metal-semiconductor contacts, Schottky diodes. Metal-semiconductor field-effect transistors, junction field-effect transistors. Laboratory. *Prerequisite: ELEN 104.* (5 units)

152. Semiconductor Devices II

Metal-oxide-semiconductor field-effect transistors, bipolar junction transistors, heterojunctions. Principles of silicon IC fabrication processes and design. Bulk and epitaxial crystal growth, thermal

oxidation, diffusion, ion implantation. Process simulation for basic devices. *Prerequisite: ELEN 151.* (5 units)

153. Digital Integrated Circuit Design

Analysis and design of digital MOS and bipolar integrated circuits. Based on first-order nonlinear device models, hand calculations and computer simulations (SPICE) used to design gates and SSIs. Circuit modeling considerations. Circuit performance evaluation with computer-aided circuit analysis. Design of MSIs from flowchart to layout. PLAs and finite state machines using array logic. Introduction to system design. (Also listed as COEN 153.) *Prerequisites: ELEN 21 and 115.* (5 units)

154. Integrated Circuit Fabrication and Characterization

Principles and practice of IC fabrication and characterization of basic semiconductor devices with experiments on oxidation, diffusion, ion implantation, lithography, etching and cleaning, metallization, film deposition, process simulation, process integration, and parameter extraction. Conducted in the Microelectronics Laboratory clean-room facility. Course includes two hours lecture and two 3-hour labs per week. *Prerequisite: ELEN 152.* (5 units)

160. Principles of Electrical Machines

Analysis of specialty machines used in control systems such as voice coil motors, stepping motors, and P.M. motors. Introduction to electronic drive systems as applied to motor control. *Prerequisite: ELEN 100.* (5 units)

161. Advanced Electrical Machine Theory

Principles of electrical machines. Introduction to magnetic circuits, induction machines, and three-phase synchronous machines. *Prerequisite: ELEN 100.* (5 units)

162. Electric Power Systems

Systems that transmit electrical energy from the point of generation to the point of use. Three-phase systems. Faults. Load flows. System modeling for computer solutions. *Prerequisite: ELEN 100 or equivalent.* May be taken for graduate credit up to 12 units. NCX† (4 units)

164. Introduction to Power Electronics

Development of models utilizing semiconductor materials used in high-current and/or high-voltage applications. Models include DC to DC converters, AC to DC converters, and DC to AC inverters. Analysis of power amplifiers. SPICE implementations of models. *Prerequisite: ELEN 115.* (5 units)

180. Introduction to Information Storage

Storage techniques and mass storage devices. Use of memory in computer systems. Design of semiconductor, magnetic and optical (disk drives), and magnetic tape memories. Storage controllers, computer interfaces, system software interfaces. Emphasis on current mass storage devices and interfaces: SCSI, IPI, ST506, ESDI. (Also listed as COEN 180.) *Prerequisites: COEN 11 and ELEN 21; ELEN 122 recommended.* May be taken for graduate credit up to 12 units. (4 units)

188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work experience relating to their academic field of study and career objectives. Alternate or parallel periods of classroom study with periods of training in industry and government. Work includes overall report on assignment activities. P/NP grading. May be taken twice. May be taken for graduate credit. Additional fees required. (2 units)

†Exempted from challenge

189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or a research project, etc., after completing the co-op assignment. Approval of department co-op adviser required. Letter grades based on content and presentation quality of report. May be taken twice. May be taken for graduate credit. (2 units)

194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project adviser. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project report. *Prerequisite: English 182.* (2 units)

195. Design Project II

Continued design and construction of the project, system, or device. Second draft of project report. *Prerequisite: ELEN 194.* (2 units)

196. Design Project III

Continued design and construction of the project, system, or device. Final report. *Prerequisite: ELEN 195.* (2 units)

199. Independent Study

Open to department scholars only. (1–6 units)

GRADUATE COURSES

Some graduate courses may not apply toward certain degree programs. As early as possible, preferably during the first quarter of study, students are urged to discuss in detail with their faculty adviser the program of study they wish to pursue.

200. Electrical Engineering Graduate Seminars

Regularly scheduled seminars on topics of current interest in the fields of electrical engineering and computer engineering. Consult department office for detailed information. P/NP grading. (Also listed as COEN 400.) (1–2 units)

210. Signals, Circuits, and Systems

Continuous and discrete signals. Circuit equations and time response. Laplace transform. Difference equations and discrete systems. Z-transform. Convolution. Transfer function. Frequency response. Fourier series and transform. Matrix representations of circuits and systems. The notion of state. State transition matrix. State and output response. (2 units)

211. Modern Network Analysis I

Graph theory and its applications to network matrix equations. Network component magnitude and frequency scaling. Network topology, graph theory, graph matrices, oriented and nonoriented graphs. Fundamental network laws. Topologically dependent matrix equations. Circuit simulation. Planar and dual graphs. Nondegenerate network state equations. *Prerequisites: ELEN 111, AMTH 245 and 246, and knowledge of Laplace transforms.* (2 units)

212. Modern Network Analysis II

Continuation of ELEN 211. State variable equations. General analysis of linear networks, including Laplace transform applications. Network analysis in the s-domain frequency response functions. Two-port and n-port networks and parameters. Indefinite admittance matrix. *Prerequisite: ELEN 211.* (2 units)

213. Linear Systems Analysis

Networks as linear systems. Application of two-port network theory to the analysis and design of feedback amplifiers and

systems. Indefinite admittance matrices in linear amplifier design. State transition matrix. Network state variable equations; discrete-time and sample data systems. Z-transforms, controllability and observability of linear systems, sensitivity and stability of linear networks and systems. *Prerequisites: ELEN 212 and 236.* (2 units)

214. Topological Study of Linear Networks

Topological analysis of passive and active linear networks; planarity and duality, passive one-ports and two-ports, flow-graph techniques, analysis of active linear networks, applications to switching networks. Introduction to topological synthesis and other applications. *Prerequisite: ELEN 211.* (2 units)

215. Network Synthesis I

Input immittance properties. Positive real functions. Synthesis of two-element kind and RLC one-ports. Synthesis of transfer functions. Properties of second-order systems. Introduction to the ideal operational amplifier. Second-order low-pass networks. *Prerequisites: ELEN 211 and 212.* (2 units)

216. Network Synthesis II

Continuation of ELEN 215. Second-order band-pass and high-pass networks. Magnitude and phase functions. Approximations. Low-pass, band-pass, and high-pass passive and active realizations. *Prerequisite: ELEN 215.* (2 units)

217. Operational Amplifier Networks

Ideal operational amplifier. Analysis of operational amplifier networks. Linear and nonlinear operational amplifier applications. Design of active RC circuits. Practical limitations of the operational amplifier. *Prerequisite: ELEN 250 or undergraduate equivalent.* (2 units)

218. Computer-Aided Circuit Analysis and Optimization

Survey of modern computer techniques for the analysis of linear and nonlinear general networks. Numerical and symbolic methods, tolerance analysis, and optimization. *Prerequisites: ELEN 212, 213 or 214, and computer programming knowledge.* (2 units)

219. Fundamentals of Computer-Aided Circuit Simulation

Introduction to the algorithms used in a circuit simulation program like SPICE, which is used extensively in the IC design. Major focus on circuit equation formulation, nonlinear system solution algorithms, sparse matrix techniques, and numerical integration methods. Work-around problems like convergence discussed. SPICE used for designing electronic circuits. *Prerequisite: ELEN 211.* (2 units)

220. Operational Amplifier Applications

Mathematics of basic operational-amplifier circuits. Applications in non-linear circuits. Broadbanding. Data acquisition systems. Sample and hold circuits. Single- and multiple-amplifier active filters. Modeling. *Prerequisites: ELEN 111 and 217.* (2 units)

229. Topics in Network Theory

(2 units)

230. Introduction to Control Systems

Descriptions of dynamic systems: state-space and frequency domain. Linear systems and feedback. Stability (Routh-Hurwitz and Nyquist tests). Design (Bode diagrams and root-locus method). PID controllers. State-variable feedback design. *Prerequisite: ELEN 210.* (2 units)

231. Design of Feedback Control Systems

Design of linear, continuous control systems utilizing techniques of the frequency

response method, root-locus, and parameter plane method. Time and frequency response correlation and steady-state analysis. *Prerequisite: ELEN 130 or 230.* (2 units)

232. Introduction to Nonlinear Systems

Basic nonlinear phenomena in dynamic systems. State space and phase plane concepts. Equilibria. Linearization. Stability. Liapunov's methods. Limit cycles. Describing function. *Prerequisite: ELEN 236.* (2 units)

233. Digital Signal Processing I

Description of discrete signals and systems. Z-transform. Convolution and transfer functions. System response and stability. Fourier transform. Sampling theorem. Digital filtering. State-space representations. (Also listed as COEN 201.) *Prerequisite: ELEN 210.* (2 units)

234. Digital Signal Processing II

Continuation of ELEN 233. Discrete Fourier transform. Digital filter design techniques. Fast Fourier transform. Quantization effects. Estimation. (Also listed as COEN 202.) *Prerequisite: ELEN 233.* (2 units)

235. Estimation

Stochastic processes. Bayesian and maximum likelihood estimation. Least-squares estimation. Kalman filter. *Prerequisite: AMTH 211.* (2 units)

236. Linear Control Systems I

Concept of state-space descriptions of dynamic systems. Relations to frequency domain descriptions. State-space realizations and canonical forms. Controllability and observability. Discrete-time systems. *Prerequisites: AMTH 245 and ELEN 210.* (2 units)

237. Optimal Control

Linear regulator problem. Hamilton-Jacobi equation. Riccati equation. Stability. Estimators. *Prerequisite: ELEN 236.* (2 units)

238. Optimization Techniques

Numerical techniques for optimization. Mathematical programming: linear, quadratic, nonlinear. Iterative techniques; gradient, Newton, dynamic programming. *Prerequisite: ELEN 237.* (2 units)

239. Topics in Systems Theory

(2 units)

241. Communication Signals

Introduction to communication signals using Fourier series and Fourier transform analysis. Linear system response. Probability and random variables. Random processes, correlation functions, and power spectra. (2 units)

242. Digital Communication Systems I

Digital message sources: PCM, DPCM, data sources. Introduction to information theory and coding. Channel capacity. Baseband digital transmission. *Prerequisite: ELEN 241.* (2 units)

243. Digital Communication Systems II

Optimal receiver principles. Spectral shaping. Digital modulation techniques: ASK, PSK, FSK, QAM, MSK. Performance. Introduction to synchronization. *Prerequisite: ELEN 242.* (2 units)

244. Information Theory

Introduction to the fundamental concepts of information theory. Source models. Source coding. Discrete channel without memory. Continuous channel. Alternate years; not offered in 1995–96. *Prerequisites: ELEN 241 and AMTH 211.* (2 units)

245. Signal Detection Theory

Signal detection in a noisy environment. Decision criteria. Hypothesis testing. Parameter estimation. *Prerequisites: ELEN 242 and AMTH 362.* (2 units)

246. Coherent Communication Theory

Use of phase-locked loops in coherent communication systems. Modulation schemes. Uncoded and coded systems. *Prerequisites: ELEN 242 and AMTH 362.* (2 units)

247. Analog Communication Systems

Analog modulation. AM, SSB, DSB, VSB, FM, and PM. Coherent and noncoherent demodulation. Performance of analog modulation systems. Threshold effects. *Prerequisite: ELEN 241.* (2 units)

248. Pulse Modulation

Sampling principle. Pulse modulation techniques. Pulse code modulation. Differential PCM. Delta modulation. Correlative techniques. Channels. *Prerequisite: ELEN 242.* (2 units)

249. Topics in Communication Theory

(2 units)

250. Electronic Circuits

Introductory presentation of semiconductor circuit theory. The p-n junction, bipolar junction transistors (BJT), field-effect transistors (JFET, MOSFET), and circuit models for these devices. DC biasing required of small-signal analog amplifier circuits. Analysis and design of small signal amplifiers, including immittance gains and frequency response. Multistage amplifiers. The ideal operational amplifier and circuit applications. May not be taken for credit by a student with an undergraduate degree in electrical engineering. *Prerequisite: ELEN 210.* (2 units)

251. Semiconductor Devices and Circuits

Silicon bipolar device modeling methods based upon process technology, device physics, and device parameter extraction. Emphasis on obtaining device parameters for diodes, bipolar junction transistors (BJT), and junction field-effect transistors (JFET) to be used with the SPICE circuit simulation program. Development of models for the p-n junction, Ebers-Moll 1, 2, and 3 (EMI, EM2, EM3), and the JFET. *Prerequisites: ELEN 250 and 261 or the undergraduate equivalent; concurrent registration in ELEN 261 is acceptable.* (2 units)

252. Transistor Circuit Design I

Utilization of the small-signal hybrid-pi and h-parameter models to study single-stage semiconductor amplifier circuits. DC biasing, bias stability, immittance and transfer functions, and frequency response characteristics. *Prerequisite: ELEN 250 or undergraduate equivalent.* (2 units)

253. Transistor Circuit Design II

Continuation of ELEN 252. Extension of analysis and design techniques of ELEN 252 to multistage amplifiers. Interstage coupling methods, and cascade amplifier design. Differential amplifier analysis and design. *Prerequisite: ELEN 252.* (2 units)

254. Feedback Amplifier Theory

Analysis and design of feedback amplifiers. Two-port multiterminal network theory, network models, and applications of the indefinite admittance matrix (IAM). Two-port feedback amplifier configurations and their network response functions. *Prerequisite: ELEN 253.* (2 units)

255. High-Frequency Transistor Circuits

High-frequency amplifier design with two-port models. Characterization of high-frequency BJT and JFET models, stability, terminations, power gain, tun-

ability, and DC bias methods. High-frequency and microwave circuit simulation. *Prerequisite: ELEN 253.* (2 units)

256. Active RC Filters

Analysis and design of active RC circuits using operational amplifiers. *Prerequisite: ELEN 252.* (2 units)

258. High-Speed Interconnect Technology

Concepts in electronic packaging. Signal line design. Attenuation, dispersion, and cross talk in lossy environments. Interconnect strategies. Power distribution and ground plane noise. Fundamental design limits (e.g., light and charge carrier speed, quantum effects, routing density). *Prerequisite: AMTH 230 or equivalent course.* (2 units)

259. Topics in Circuit Design

(2 units)

261. Fundamentals of Semiconductor Physics

Wave mechanics. Crystal structure and energy band structure of semiconductors. Carrier statistics and transport. Electrical and optical properties. (2 units)

264. Semiconductor Device Theory I

Physics of semiconductor materials, junctions, and contacts as a basis for understanding all types of semiconductor devices. *Prerequisite: ELEN 261.* (2 units)

265. Semiconductor Device Theory II

Continuation of ELEN 264. Bipolar transistors, MOS and junction field-effect transistors, and semiconductor surface phenomena. *Prerequisite: ELEN 264.* (2 units)

266. Integrated Circuit Design

Survey of monolithic processes and integrated components. Analysis and design of simple MOS and bipolar integrated circuits. Integrated design techniques. Basic MOS and bipolar logic gates, memories, and amplifiers. Fundamental design concepts and differences between discrete and integrated circuit design. *Prerequisites: ELEN 265 and 274.* (2 units)

267. Analog Bipolar Integrated Circuit Design

Review of op-amp networks, frequency response to linear integrated circuits, feedback amplifiers, stability, multipliers and phase detectors, voltage controller oscillators, phase-locked loops. *Prerequisite: ELEN 266.* (2 units)

268. Digital Bipolar Integrated Circuit Design

Ebers-Moll and charge control models of a bipolar transistor. Resistor-transistor logic. Diode-transistor logic. Schottky TTL emitter-coupled logic. Flip-flops. Memories. Interfacing bipolar and MOS gates. *Prerequisite: ELEN 266.* (2 units)

274. Integrated Circuit Fabrication Processes I

Fundamental principles of silicon-integrated circuit fabrication processes. Practical and theoretical aspects of microelectronic fabrication. Basic materials properties, including crystal structure and crystallographic defects; physical and chemical models of crystal growth; and doping, thermal oxidation, diffusion, and ion implantation. *Prerequisite or corequisite: ELEN 264.* (2 units)

275. Integrated Circuit Fabrication Processes II

Physical and chemical models of etching and cleaning, epitaxy, deposited films, photolithography, and metallization. Process simulation and integration. Principles and practical aspects of fabrication of devices for MOS and bipolar integrated circuits. *Prerequisite: ELEN 274.* (2 units)

276. Hybrid Processing

Materials and processes for thin- and thick-film hybrid circuits and systems. Packaging materials and methods. *Prerequisite: ELEN 264.* (2 units)

279. Topics in Semiconductor Devices and Processing

(2 units)

280. Power Transmission System

Calculation of transmission line parameters. Sequence impedances, bundled conductors, multiplex calculations. Introduction to EHV systems, AC and DC operation. Environmental effects of EHV systems. *Prerequisite: ELEN 701.* (2 units)

281. Introduction to Electric Power Systems I

Introduction to power network modeling. Development of mathematical models and the mathematics for network solutions, matrices, linear and nonlinear equations and their solution techniques. Symmetrical components, iteration network reduction techniques. (2 units)

282. Introduction to Electric Power Systems II

Numerical analysis, load flow studies, load representation, transformer modeling. Development of reduction techniques including triangularization and diakoptics. Network equivalents. *Prerequisite: ELEN 281.* (2 units)

283. Introduction to Electric Power Systems III

Analysis of power networks under faulted conditions. Balanced three-phase and unbalanced faults. Development of symmetrical components. *Prerequisite: ELEN 281 or equivalent.* (2 units)

284. Power Systems Control I

Reactive power control techniques. Power factor correction and voltage control. (2 units)

285. Electromechanical Rotating Device Theory

Introduction to mechanical and electrical dynamics of synchronous machines. Excitation system and modeling of AC machines. Induction motor transients. *Prerequisite: ELEN 161 or equivalent.* (2 units)

286. Power System Stability

Modeling of fossil-fuel, nuclear, and waterwheel power plants. Excitation systems and controls. Two machine stability, equal area criterion, and swing equations. Large-system dynamics, mechanical and electrical transients. *Prerequisite: ELEN 285.* (2 units)

287. Distribution System Planning

Planning techniques as applied to electrical utility distribution planning. Analytical techniques and computer applications. Load forecasting and load management. Voltage control by reactor and capacitor methods. Optimum placement of capacitor or radial feeders. Power factor correction. Transformer management. Load energy management control using microprocessor applications. Distribution automation. *Prerequisite: ELEN 281 or equivalent.* (2 units)

288. Electric Power Transients

Switching transients in electric power systems. Analysis of effects of lightning on transmission and distribution circuits. Transients in direct current systems. Traveling wave phenomenon. *Prerequisite: ELEN 280.* (2 units)

289. Topics in Power Systems

(2 units)

297. Master's Thesis Research

By arrangement. (1–9 units)

298. Ph.D. Thesis Research

By arrangement. A nominal number of 45 units is expected toward Ph.D. degree. (1–15 units)

299. Independent Study

Special problems and/or research. By arrangement. (1–6 units)

320. Topics in Computational Intelligence

(2 units)

328. Soft Expert Systems

Soft computing with neural networks and fuzzy logic. Expert system architecture. Approximate reasoning and vagueness in expert systems. Expert control and other applications. (2 units)

329. Introduction to Intelligent Control

Intelligent control, AI, and system science. Adaptive control and learning systems. Artificial neural networks and Hopfield model. Supervised and unsupervised learning in neural networks. Fuzzy sets and fuzzy control. (Also listed as MECH 329.) *Prerequisite: ELEN 236.* (2 units)

330. Linear Control Systems II

Realization theory. Canonical forms. State-variable feedback. Asymptotic observers. Compensator design. *Prerequisite: ELEN 236.* (2 units)

331. Stochastic Control

Stochastic state models. Dynamics programming. State estimation. Linear-quadratic-Gaussian (LQG) design. *Prerequisites: AMTH 211 and ELEN 237.* (2 units)

332. Nonlinear Control Systems

Continuation of ELEN 232. Feedback. Absolute stability. Positive realness and Popov's method. Interconnected and complex systems: uncertainty. Decentralized control: robustness. Singular perturbations. Feedback linearization. *Prerequisites: ELEN 232 and 236.* (2 units)

333. Digital Control

Difference equations. Z-transforms. Transfer functions. State-space models. Root-locus method. Linear regulator design. *Prerequisites: ELEN 130 and 236.* (2 units)

334. Introduction to Statistical Signal Processing

Introduction to statistical signal processing concepts. Random variables, random vectors, and random processes. Second-moment analysis, estimation of first and second moments of a random process. Linear transformations; the matched filter. Spectral factorization, innovation representations of random processes. The orthogonality principle. Linear predictive filtering; linear prediction and AR models. Levinson algorithm. Burg algorithm. MATLAB Computer assignments. *Prerequisites: ELEN 233 and either AMTH 245 or knowledge of linear algebra.* (2 units)

335. Optimal Filtering

Gauss–Markov models. Discrete Kalman filter. Stationary behavior. Wiener filter. Continuous Kalman filter. Extensions. *Prerequisites: ELEN 235 and 236.* (2 units)

336. Identification

Identification problem. Recursive identification. Extended Kalman filter. Convergence. Implementation. *Prerequisites: ELEN 235 and 236.* (2 units)

337. Robotics I

Overview of robotics: control, AI, and computer vision. Components and structure of robots. Homogeneous transformation. Forward kinematics of robot arms. Denavit–Hartenberg representation. Inverse kinematics. Velocity kinematics. Manipulator Jacobian. Singular configurations. Euler–Lagrange equations. Dynamic equations of motion of manipulators. Task planning, path planning, and trajectory planning in the motion control problem of robots. (Also listed as MECH 337.) *Prerequisite: AMTH 245.* (2 units)

338. Robotics II

Joint-based control. Linear control of manipulators. PID control and set-point tracking. Method of computer-torque in trajectory following control. (Also listed

as MECH 338.) *Prerequisites: ELEN 236 and 337.* (2 units)

339. Robotics III

Intelligent control of robots. Neural networks and fuzzy logic in robotic control. Selected topics of current research in robotics. (Also listed as MECH 339.) *Prerequisite: ELEN 338.* (2 units)

345. Phase-Locked Loops I

Basic loop. Components. Describing equations. Stability. Transients. Modulation and demodulation. *Prerequisite: ELEN 242.* (2 units)

346. Phase-Locked Loops II

Additive noise response. Random modulation. Nonlinear operation with noise. Cycle-slipping. *Prerequisite: ELEN 345.* (2 units)

347. Advanced Digital Communication Systems

Uncoded systems vs. channel capacity. Channel coding: trellis codes, multidimensional modulation, block codes. Intersymbol interference. Equalization. Adaptive equalization. Performance. MLSD. *Prerequisite: ELEN 243.* (2 units)

351. Applied Acoustics I

Introduction to field of acoustics including the wave theory of sounds; quantitative measures of sound; the reflection, transmission, and excitation of plane waves; and radiation from vibrating bodies. (2 units)

352. Applied Acoustics II

Continuation of ELEN 351 with applications in speech and hearing noise and other areas of special interest. *Prerequisite: ELEN 351.* (2 units)

371. Digital MOS Integrated Circuit Design I

Analysis and design of NMOS/CMOS building blocks: inverters, logic gates, tristate gates, multiplexers, demultiplexers, decoders, I/O drivers, ESD and input protection networks, latches, S-R flip-flops, master-slave D flip-flops. Domino logic design techniques. Design of registers, counters, and programmable logic arrays. Layout and floor-plan considerations, stick diagrams, routing of global signals, and layout verification. *Prerequisite: ELEN 266.* (2 units)

372. Digital MOS Integrated Circuit Design II

Organization and design of memory circuits: DRAMs, SRAMs, ROMs, EPROMs, EEPROMs, and Flash EEPROMs. Design of memory cells, decoders, sense amplifiers, bitline precharge circuits, divided work-line architecture, synchronous vs. asynchronous memories, timing diagrams, layout design considerations, reliability issues. *Prerequisite: ELEN 371.* (2 units)

373. Optical Communications I

Review of III–V semiconductor hetrostructures and quantum wells. Optical emission from semiconductors (spontaneous and simulated). Einstein relations. Population inversion. Optical feedback and laser oscillation. Light-emitting diodes. Laser diodes: structures and operation. Photodetectors: PIN and Avalanche. Semiconductor laser amplifiers. Optoelectronic integrated circuits. *Prerequisite: ELEN 264.* (2 units)

374. Optical Communications II

Continuation of ELEN 373. Optical fibers. Optical transmitter and receiver modules. Optical fiber amplifiers. Optical fiber systems: design considerations and system performance. *Prerequisite: ELEN 373.* (2 units)

375. Semiconductor Surfaces and Interfaces

Structural and electronic properties of semiconductor surfaces, semiconductor/oxide interfaces, and metal/semiconductor interfaces. Relationship between interface morphology/composition and electrical properties. Modern techniques for characterizing surfaces and interfaces.

Derivation of interface properties from electrical characterization of devices. *Prerequisite: ELEN 265.* (2 units)

376. Hybrid Circuit Design

Design of thin- and thick-film hybrid systems. Hybrid components. *Prerequisite: ELEN 265.* (2 units)

377. Microwave Integrated Circuits I

Fabrication and design of Si and GaAs microwave integrated components. MMIC analysis and testing. *Prerequisite: ELEN 265.* (2 units)

378. Microwave Integrated Circuits II

Continuation of ELEN 377. *Prerequisite: ELEN 377.* (2 units)

379. Topics in Microelectronics

(2 units)

380. Advanced CMOS and BiCMOS Technologies

Advanced CMOS and BiCMOS structures. Device parameter optimization for scaling PMOS, NMOS, and BJT simultaneously. Novel CMOS structures, retrograde well, halo junction, p^+-poly gate, preamorphization, poly-LLD structures. Submicron lithography, submicron isolation, self-aligned contact, dielectrics, low-temperature CMOS characteristics. BiCMOS device technology, BiCMOS device integration, polyemitter structures. Submicron BiXMOS structures and process trade-offs. Trench capacitor memory cells, EPROM, and Flash memory cells. *Prerequisite: ELEN 265.* (2 units)

381. Analog MOS Integrated Circuit Design I

Small-signal circuit behavior. Design of CMOS building blocks including current mirrors, gain stages, differential amplifiers. Frequency response of MOS building blocks. Design of MOS operational amplifiers and comparators. *Prerequisite: ELEN 266.* (2 units)

382. Analog MOS Integrated Circuit Design II

Offset, noise and distortion, and means of reducing them in CMOS circuits. Design of A/D and D/A converters, reference voltages, and switched capacitors filters. *Prerequisite: ELEN 381.* (2 units)

383. VLSI Device Theory

Small-geometry effect in BJT and MOSFET for VLSI applications. Trade-offs in optimization of VLSI device structures. MOS scaling using constant-field and constant-voltage constraints, LDD structures. CMOS latchup study and prevention. Isolation techniques: junction, oxide, and trench isolation. Bipolar device scaling, self-aligned bipolar devices. MESFET and SOI devices. *Prerequisite: ELEN 265.* (2 units)

384. VLSI Device Modeling

Physical models for BJT and MOSFET. Semiconductor device equations and their iterative solution. Numerical techniques used in device simulations. MOS capacitor models, submicron CMOS models, LDD-MOSFET device modeling, device parameter extraction, trade-off in model selection. Device parameter design and optimization using simulation tools. Device characterization and parameter extraction techniques. BJT device modeling. Application of device modeling in circuit design. *Prerequisite: ELEN 265.* (2 units)

385. VLSI Fabrication Technology I

Overview of materials analysis techniques such as SEM/EDX/WDX, AES, ESCA, SIMS, RBS, FIB, and TEM/ED. Plasma etch, ion mill, reactive ion etch, and sputtered-etch processes. X-ray and E-beam lithography techniques. Assembly and packaging of integrated circuits with focus on high-pin-count surface-mount packages. Overview of bipolar and CMOS VLSI processes. *Prerequisite: ELEN 275.* (2 units)

386. VLSI Fabrication Technology II

Process-related reliability issues. Process integration in VLSI. Yield-limiting process considerations. Process equipment, IC manufacturing, and automation. Contamination-induced defects in submicron and class-near-zero clean-room processing environments. Topics in III-V process technologies. *Prerequisite: ELEN 385.* (2 units)

387. VLSI Design I

Introduction to VLSI design methodology; hierarchical full custom design of CMOS digital circuits; design abstractions, lambda-based design rules, scaling, ratioed and switch logic, different logic structures; regular arrays, chip floor plans; timing models; distribution of global power, clock, and other buses. Use of various VLSI design CAD tools—schematic entry, place and route, and VHDL simulators. Examples of design of subsystems. (Also listed as COEN 203.) *Prerequisites: ELEN 115 and 500 or equivalent.* (2 units)

388. VLSI Design II

Continuation of design methodologies. Semicustom vs. custom designs. Hierarchical design of semicustom chips. ASIC designs. Programmable logic arrays, gate arrays, standard cells. Principles of placement and routing. Top-down design. Design verification. Examples of design of subsystems. (Also listed as COEN 204.) *Prerequisite: ELEN 387.* (2 units)

389. Silicon Compilation

Techniques used for computer-aided design of VLSI circuits. Layout compaction, procedural design, and module generators. Algorithms for placement, floor planning, and routing. PLA and gate-matrix compaction. Heuristic, deterministic, and probabilistic algorithm design and analysis for VLSI. Logic, structural, and behavioral synthesis and optimization. Principles and examples of silicon compilers. Expert systems for silicon compilation. (Also listed as COEN 305.) *Prerequisite: ELEN 388.* (2 units)

431. Adaptive Signal Processing I

Theory of adaptive filters, Wiener filters, the performance surface, gradient estimation. The least-mean-square (LMS) algorithm, other gradient algorithms, transform-domain LMS adaptive filtering, block LMS algorithm. IIR adaptive filters. The method of least squares. Recursive least squares (RLS) adaptive transversal filters; application of adaptive filters in communications, control, radar, etc. Projects. *Prerequisites: ELEN 233 and either ELEN 334 or AMTH 362 or knowledge of random processes.* (2 units)

432. Adaptive Signal Processing II

Linear prediction. Recursive least squares lattice filters. Applications of Kalman filter theory to adaptive transversal filters. Performance analysis of different algorithms. Fast algorithms for recursive least squares adaptive transversal filters. Applications of adaptive filters in communications, control, radar, etc. Projects. *Prerequisite: ELEN 431.* (2 units)

433. Array Signal Processing

Statistical analysis of array signal processing of a spectral analysis and direction-finding. Classical spectral analysis, maximum entropy, minimum variance, maximum likelihood, and super-resolution techniques. Alternate years; not offered 1996–97. *Prerequisites: ELEN 234 and either ELEN 235 or AMTH 362.* (2 units)

435. Artificial Neural Networks

Neural network paradigms; biological and artificial neuron. Different models and architectures for neural networks. Feedforward networks and feedback networks. Static and dynamic neural networks. Associative networks. Mapping networks. Applications of neural networks. Training laws for neural networks; perceptrons, perceptron convergence theorem, Hebb's Rule, Adalines, Madalines, Hopfield Nets, Bolzman Nets, BackPropagation, etc. Analysis of neural networks; performance surfaces, stability issues, etc. VLSI implementation of neural nets. Student projects. Alternate years; not offered

1996–97. *Prerequisites: AMTH 245, ELEN 233, and either ELEN 334 or AMTH 362.* (2 units)

439. Topics in Adaptive Signal Processing

(2 units)

441. Communication Satellite Systems Engineering

Satellite systems engineering considerations. Satellite power budgets, multiple access problems. Earth station characteristics. Modulation schemes. *Prerequisite: ELEN 242 or equivalent.* (2 units)

444. Error-Correcting Codes

Theory and implementation of error-correcting codes. Linear block codes, cyclic codes. Encoding and decoding techniques and implementations analysis of code properties and error probabilities. Alternate years; not offered 1995–96. *Prerequisite: ELEN 244.* (2 units)

451. Magnetism and Magnetic Recording Materials

Origin of magnetism. Intrinsic and extrinsic properties of magnetic materials that determine their behavior in magnetic recording. Coercivity mechanisms, M-H loops, and possible future developments in magnetic materials. Measurements. Nonmagnetic properties of materials and their importance. (2 units)

453. Information Storage Systems

Overview of storage systems. Magnetic disk, tape, optical and flash memory devices viewed in terms of cost/performance design trade-offs and advances in technologies and new applications. (2 units)

454. Optical Recording

Optical components, design aspects of optical recording systems, and optical media. Write-once/read-only and reversible optical storage. Applications and performance characteristics. (2 units)

456. Configuration of Rigid Disk Drives

Configuration of small disk drives. Study of elements of a disk drive including head, medium, mechanics, and electronics to understand the trade-offs involved in engineering such devices. (2 units)

457. Partial-Response Recording

Overview of magnetic recording process and review of linear systems applicable to communication theory. Partial response signals defined and studied in continuous time, discrete time, and frequency domains. Concept of maximum likelihood detection; Viterbi algorithm. Performance of partial-response systems in terms of minimum-distance error events. G/I modulation coding and spectral null codes. Timing recovery and nonlinear transition shift. Alternative detection techniques. (2 units)

458. Signal Processing and Coding for Data Storage and Transmission

Introduction to signal processing and coding with emphasis on applications to information storage and transmission devices. Examples of current practical interest illustrate the techniques presented. *Prerequisite: ELEN 241.* (2 units)

460. Magnetic Recording Theory I

Magnetic recording process. Magnetic material properties and fields, demagnetization. Readback, including application of reciprocity, pulse and sine wave recording, loss factors. Longitudinal and perpendicular modes of recording. Magnetic head-medium design principles. *Prerequisite: ELEN 701.* (2 units)

461. Magnetic Recording Theory II

Continuation of ELEN 460. Write process: models, transition region, head and medium parameter influence, overwrite. Magnetic recording channel, roll-off curves, bit shift, signal processing tech-

niques, signal-to-noise issues. *Prerequisite: ELEN 460 or permission of instructor.* (2 units)

462. Advanced Recording Theory

Selected topics in magnetic recording theory. *Prerequisite: ELEN 461.* (2 units)

463. Disk Drive Channel Integration

Recording channel design considerations. Noise sources, head and disk components, and recording channel electronics. Track misintegration. Track density issues: off-track capability, 747 curves, and adjacent track interference. Error rate estimations. *Prerequisite: ELEN 460; ELEN 461 recommended.* (2 units)

465. High-Performance Head Positioning Servosystems

Recording head positioning via voice coil motors, transfer functions, course positioning, fine tracking, compensation for mechanical resonance and performance. *Prerequisite: a background in amplifiers, feedback control systems and elementary electronics, and circuits and mechanics.* (2 units)

466. Digital Servo Systems for Disk Drives

Continuation of ELEN 465. Transform and state-space techniques. Random neighborhood search and proximate-time optimal techniques for track following and seeking optimizations. Micro Code implementation using Time Domain Quantization Simulation. Emphasis on design, simulation, and implementation for higher-track density requirements of modern disk drives. *Prerequisites: ELEN 465 or background in the subject matter covered.* (2 units)

468. Magnetic Circuit Design

Properties and characteristics of magnetic materials: fine particles, thin and thick films, bulk materials. Saturation. Magnetic circuit models, fundamentals of magnetic design. Design of selected devices. *Prerequisite: ELEN 701.* (2 units)

469. Magnetic Recording Head Design

Design and evaluation of magnetic recording heads and structures. Ferrite, thin-film metal-in-gap, and composite designs. Magneto-resistive sensors. Saturation effects. Finite element analysis concepts. *Prerequisite: ELEN 468.* (2 units)

470. Read/Write Magnetic Recording Circuits

Time domain and frequency domain responses of single- and multistage wideband amplifiers; wave shaping: clipping, clamping, limiting, comparator and switching circuits; time-base generators; read/write magnetic recording circuits. Continues coverage on preamplifiers, drivers, encoders, compensation, phase-locked loops, safety circuits, design, and testing. *Prerequisite: ELEN 252; ELEN 231 and 345 recommended.* (2 units)

473. Introduction to Storage Subsystems

Memory/storage hierarchy and the interaction of memory and storage in computer systems. Controller design, interfaces and protocols, error handling. DMS. Emphasis on SCSI and PC-AT. (2 units)

474. Storage Architecture

Workstation storage requirements. Buffers and disk cache architectures. Storage system performance: seek, latency, overhead, and throughput. The use of ASICs, firmware, and microprocessors in modern storage controllers. Emphasis on SCSI, PCMCIA, PCI. Disk arrays and RAID architectures. *Prerequisite: ELEN 473.* (2 units)

475. Advanced Storage Architecture

Special topics in storage architecture. *Prerequisite: ELEN 474.* (2 units)

477. Numerical Computation of Static Fields

Finite element method and integral equation method as applied to field computations. Construction of finite elements,

node points, shape and basis functions, and the linear space in which the solution lies. Projection methods. Examples. *Prerequisites: ELEN 104 and AMTH 245 and 246.* (2 units)

478. Field Computation Laboratory

Numerical computation of static fields. Construction and implementation of computer programs with outputs displayed on graphics terminals and on hard copy. Finite element and integral equation method. (2 units)

479. Special Topics in Information Storage Technology

(2 units)

480. DC Machine Theory

Analysis of DC machine characteristics in steady state and in transient state. Transfer functions, state variables, and analytical methods of analysis. *Prerequisite: ELEN 285.* (2 units)

481. Power Systems Control II

Concepts of modern control theory applied to theory of eigenvalue sensitivity analysis; linear analysis of load-frequency control of power systems. *Prerequisites: ELEN 236 or equivalent and 284.* (2 units)

482. Advanced Electric Motor Systems Modeling

Continuation of ELEN 285. Emphasis on transient analysis of induction machines. Introduction to variable frequency drives for three-phase induction motors. *Prerequisite: ELEN 285.* (2 units)

483. Power Systems Protection Method

Analysis of relaying schemes for protection of interconnected systems, as well as relaying distribution networks. Introduction to digital relaying. *Prerequisite: ELEN 480.* (2 units)

484. Electrical Transients

Analysis of switching transients, as well as transients due to external faults. Evaluation of the EMTP computer program. (2 units)

485. Power Electronics I

Introduction to power electronic device theory. Methods of control of such elements in various converter and inverter systems. (2 units)

486. Power Electronics II

Continuation of ELEN 485. Emphasis on use of the devices for application to electric motor drive systems. *Prerequisite: ELEN 485.* (2 units)

487. Electronic Machine Drives

Analysis and design of DC motor drives, variable frequency AC drives, and other applications of power electronics in control mode. *Prerequisite: ELEN 486.* (2 units)

488. Power Systems Harmonics

Analysis of nonsinusoidal waves. Power development in nonsinusoidal circuits. Causes of network distortions and their effects on modern technology. *Prerequisite: ELEN 281.* (2 units)

489. Special Problems in Power Networks

Prerequisite: permission of instructor. (1–6 units)

500. Advanced Digital Design

Analysis and synthesis of combinational and sequential digital circuits with attention to static, dynamic, and essential hazards. Algorithmic techniques for logic minimization, state reductions, and state assignments. Decomposition of state machine, algorithmic state machine. Design for test concepts. (Also listed as COEN 200.) *Prerequisite: ELEN 127C.* (2 units)

510. Computer Architecture I

Overview of major subsystems of small- to medium-scale digital computers. Machine instruction set characteristics. Typical arithmetic and logic unit functions, register dataflow organization, busing schemes, and their implementations. Computer memory systems; addressing techniques. Methods of system timing and control; hardware sequencers, microprogramming. Register transfer language and micro-operation. I/O subsystem structure; interrupts; direct memory access and I/O bus interfacing techniques. Detailed computer design project. *Prerequisites: ELEN 127C and COEN 11C or equivalent.* (2 units)

511. Computer Architecture II

Machine organization and computation structure survey. Processor issues, ALU design, fixed- and floating-point numbers and their representations. Computer arithmetic algorithms. Multioperation processors. Control unit pipelining, operation overlap, control unit look-ahead. Address processing, paging, and segmentation. Interrupt handling on different machines. Virtual machine concept. Memory hierarchies, cache, main, secondary, and backup memories. Different busing structures and I/O interconnection networks. *Prerequisite: ELEN 510.* (2 units)

600. Switching Theory

Set theory. Boolean algebra. Two- and multilevel minimization techniques. Threshold logic. Sequential machines. Iterative networks. Pulse and fundamental mode operations. State reduction. Indistinguishability and compatibility. Decomposition (partitioning) of FSM. State assignments and the covering problem. Formal hardware verification. Reliability. Boolean difference. Reed–Mueller expansion. Linear feedback shift registers. Error correcting codes. (Also listed as COEN 209.) *Prerequisite: ELEN 127C.* (4 units)

601. Logic Synthesis

Synthesis strategy. Hardware description language and its applications in synthesis. Cost elimination. Multilevel logic synthesis and optimization. Synthesis methods and systems. Module generation. Timing considerations. Area vs. speed trade-offs. Design simulation and verification. Heuristic techniques. CAD tools. (Also listed as COEN 301.) *Prerequisites: ELEN 500, ELEN 600, and COEN 210.* (2 units)

603. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Different views of HDL— structural, register transfer, and behavioral. Simulation and synthesis of systems descriptions. (Also listed as COEN 303.) *Prerequisite: ELEN 500 or the equivalent.* (2 units)

604. Semicustom Design with Programmable Devices

Digital circuit design methodologies. Semicustom implementations. Programmable logic devices—classification, technology, and utilization. Software tools—synthesis, placement, and routing. Design verification and testing. (Also listed as COEN 304.) *Prerequisite: ELEN 500 or the equivalent.* (2 units)

606. Integrated Circuits Testing

Fundamental principles of testing digital circuits. Mapping of physical defects into failure modes and fault models. Dependence of the fault models on the technology. Parametric and Boolean testing. Deterministic and probabilistic techniques for test pattern generation. Techniques for testing memories and microprocessors. Use of computer-aided testing (CAT) tools. (Also listed as COEN 306.) *Prerequisite: ELEN 500 or equivalent courses.* (2 units)

608. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. AD hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST)

techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. (Also listed as COEN 308.) *Prerequisite: ELEN 606 or the equivalent.* (2 units)

609. Fault-Tolerant Digital Systems

Hardware and software techniques for meeting stringent reliability demands with digital systems. Hardware redundancy techniques. Concurrent checking techniques. Error-detecting and error-correcting codes. Other related topics of interest. (Also listed as COEN 309.) *Prerequisite: ELEN 510.* (2 units)

610. Digital Testing with ATE

Identification of design-, manufacturing-, and packaging-induced faults. Static and dynamic electrical tests under normal and stressed conditions. Architecture of different automatic test equipment (ATE) and their corresponding test programming software environments. Test-result logging for statistical process control. (Also listed as COEN 310.) *Prerequisites: ELEN 250 and 500.* (2 units)

616. Application-Specific Array Processors

Introduction to algorithm-based application-specific designs. Systolic arrays. Wavefront arrays. SIMD and MIMD applications-specific designs. Algorithms for systolic arrays. Mapping techniques. Matching and partitioning. Formal design specifications and verifications. Systolic temporal arithmetic. System organization: host, control, interfacing, processor arrays, interconnection networks. Industrial systems. Software for array processors. Applications of systolic arrays to DSP, image processing, neural networks, etc. (Also listed as COEN 316.) *Prerequisite: ELEN 510.* (2 units)

617. Input-Output Devices

Card readers, line printers, disks, drums, magnetic tapes, keyboards, CRTs; analog-to-digital and digital-to-analog converters. (Also listed as COEN 217.) *Prerequisite: ELEN 510.* (2 units)

618. Input-Output Structures

Data transfers: synchronous and asynchronous; device selection and control; interfacing. Interrupt architectures; direct memory access. Channels, I/O processors. (Also listed as COEN 218.) *Prerequisite: ELEN 617.* (2 units)

640. Digital Image Processing I

Digital image representation and acquisition; Fourier, Cosine, Walsh, and wavelet transforms; linear and nonlinear filtering; image enhancement; morphological filtering. (Also listed as COEN 340.) *Prerequisite: ELEN 234.* (2 units)

641. Image Compression

Relationship of digital picture capture, communication, and display systems to information theory concepts of redundancy, rate, and distortion. Lossless coding techniques; Huffman coding, run-length coding for two-dimensional signals. Performance of lossy compression techniques; DPCM, transform coding, sub-band coding. Application to facsimile, video conferencing. *Prerequisites: ELEN 640 and AMTH 211.* (2 units)

642. Medical Imaging

Image formation from noninvasive measurements in computerized tomography, magnetic resonance imaging, and other modalities used clinically and in research. Analysis of accuracy and resolution of image formation based on measurement geometry and statistics. Alternate years; not offered 1995–96. *Prerequisites: AMTH 211 and either ELEN 234 or AMTH 358.* (2 units)

643. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domain; matrix representations; blind deconvolution; reconstructions from incomplete data; image segmentation methods. (Also listed as COEN 343.) *Prerequisite: ELEN 640.* (2 units)

644. Computer Vision I

Introduction to image understanding, sensor models, image enhancement and restoration for vision, stereo vision, pattern recognition, segmentation, high-level scene interpretation, human vision. (Also listed as COEN 344.) Alternate years; not offered 1996–97. *Prerequisites: ELEN 233 or 640 and either ELEN 235 or AMTH 211.* (2 units)

645. Computer Vision II

Current topics in image understanding research, 3D vision, regularization, energy function minimization; robust techniques, neural networks, symbolic processing. (Also listed as COEN 345.) Alternate years; not offered 1996–97. *Prerequisite: ELEN 644.* (2 units)

649. Topics in Image Processing and Analysis

(2 units)

697. Research Seminar in Digital Systems

Advanced topics in digital systems—design and test synthesis. Themes vary yearly: for example, memory devices, effect of GaAs on performance and reliability, mixing technologies, etc. Students are expected to investigate current research and practices and give oral presentations. (Also listed as COEN 397.) *Prerequisite: permission of instructor.* (2 units)

701. Electromagnetic Field Theory I

Time varying electromagnetic field concepts starting with Maxwell's equations. Development of field theorems. Development of circuit theory from Maxwell's equations. Transmission lines, including transient effects, losses, and coupling. Plane waves, reflection and refraction at interfaces. *Prerequisite: an undergraduate electromagnetic field course.* (2 units)

702. Electromagnetic Field Theory II

Solution of boundary value problems in rectangular, cylindrical, and spherical coordinates employing Green's functions. Applications include circular waveguides and resonators, dielectric waveguides and resonators, and antennas. *Prerequisite: ELEN 701.* (2 units)

703. Advanced Electromagnetic Field Theory I

Advanced problems in electromagnetic fields. *Prerequisite: ELEN 702.* (2 units)

704. Advanced Electromagnetic Field Theory II

Continuation of ELEN 703. *Prerequisite: ELEN 703.* (2 units)

705. Computer-Aided Design for Microwaves

A survey of approaches to CAD and to existing CAD software packages. Extensive applications in microwaves. Modeling, synthesis, algorithms, optimization. *Prerequisite: ELEN 144.* (2 units)

706. Microwave Circuit Analysis and Design

Microwave circuit theory and techniques. Emphasis on microwave integrated circuits (MIC) and waveguides. Planar transmission lines include microstrip, coplanar waveguides, and slotline. Field problems formulated into network problems for TEM and other structures. Transmission line theory, impedance, scattering and transmission parameters, Smith charts, impedance matching, and transformation techniques. *Prerequisite: ELEN 701.* (2 units)

707. Passive Microwave Devices

Passive component analysis and design with emphasis on MIC. Narrow- and wide-band filters, couplers, hybrids, and dividers. Ferrite and garnet materials. Design of isolators, circulators, phase shifters, and YIG filters. *Prerequisite: ELEN 706.* (2 units)

708. Microwave Network Synthesis I

Microwave circuit design. Realizability for commensurate networks. Approximation methods. Unit-element networks. *Prerequi-*

sites: ELEN 211 and 212; course work on complex variables recommended. (2 units)

709. Microwave Network Synthesis II

Continuation of ELEN 708. Stub-unit-element networks. Broadband matching. Applications to circuit theory. Laboratory CAD work. *Prerequisite: ELEN 708.* (2 units)

711. Active Microwave Devices I

Scattering and noise parameters of microwave transistors, physics of silicon bipolar and gallium arsenide MESFET transistors, device physics, models, and high-frequency limitations. Applications to microwave amplifier and oscillator designs. *Prerequisite: ELEN 251.* (2 units)

712. Active Microwave Devices II

Continuation of ELEN 711. Emphasis on linear active circuits and computer-aided design techniques. *Prerequisite: ELEN 711.* (2 units)

713. Microwave Semiconductor Circuit Design

Fundamentals and techniques for nonlinear microwave circuit design using Schottky diodes and FETs exemplified by Schottky diode detector design; design of control circuits using PIN diodes and FETs, with examples from switches, phase shifters, limiters, frequency multipliers and harmonic generators. *Prerequisite: ELEN 706; ELEN 707 recommended.* (2 units)

714. Nonlinear Microwave Device Modeling

Continuation of ELEN 712. Nonlinear models of diodes, bipolar transistors, and FETs applied to the design of frequency converters, amplifiers, and oscillators. Techniques. *Prerequisites: ELEN 251 and 711.* (2 units)

715. Antennas I

Fundamentals of radiation, antenna pattern, directivity and gain. Linear antennas. Linear and planar phased arrays. Broadband antennas. Antennas as components of communications and radar systems. *Prerequisite: ELEN 701.* (2 units)

716. Antennas II

Continuation of ELEN 715. Aperture, horn, reflector, and lens antennas. Antenna CAD. Moment methods for antenna elements, arrays, and complex structures. Scattering. Radar cross section. Antenna measurements. *Prerequisite: ELEN 715.* (2 units)

717. Antennas III

Continuation of ELEN 716. Printed microstrip antennas. Large antenna design. High-frequency techniques. Geometrical optics. Physical optics. Diffraction. Antenna synthesis. *Prerequisite: ELEN 716.* (2 units)

718. Antenna Design and Measurement Project

Real-world design; fabrication and testing of a practical antenna. *Prerequisites: ELEN 717 and permission of instructor.* (2 units)

720. Noise in Circuits and Devices

Sources of noise, including thermal, shot, trap and 1/f noise studied for devices such as diodes, transistors, and resistors. Analytic treatment of noise power in linear electronic circuits and devices. Treatment of amplitude and phase noise in nonlinear systems based on noise statistics and frequency characteristics with examples of mixers, phase-locked loops, and oscillators. *Prerequisite: a course in random processes.* (2 units)

721. Millimeter Wave Engineering

Fundamentals and design of millimeter-wave circuits and components. Metallic and dielectric waveguides. Integrated transmission lines and passive devices. Solid-state millimeter-wave circuits including detectors, frequency multipliers, negative resistance amplifiers, and limiters. *Prerequisites: ELEN 706 and 707; ELEN 713 recommended.* (2 units)

725. Introduction to Optical Devices

Maser and laser operation based on classical concepts and electrical engineering analogies. Applications of masers and lasers. *Prerequisite: ELEN 701 or Physics 112.* (2 units)

726. Microwave Measurements, Theory, and Techniques

Theory comprises six classroom meetings covering signal flowgraphs, error models and corrections, S-parameter measurements, scalar and vector analyzers, microwave resonator measurements, noise figure measurements, signal generation and characterization, spectrum analyzers, and phase noise measurements. Four laboratory meetings. *Prerequisite: ELEN 711 or 713.* (2 units)

729. Topics in Electromagnetic Field Theory

Selected advanced topics in electromagnetic field theory. *Prerequisite: as specified in class schedule.* (2 units)

ENGINEERING MANAGEMENT

Professor: Robert J. Parden *(Director)*

GRADUATE COURSES

250. Introduction to Engineering Management I

Business organizations. The business environment, strategies, objectives, decision making, organizing, delegation, participation, monitoring, and quality control. (2 units)

251. Production and Operations Management

Planning and controlling operations, operations strategy, inventory and capacity planning, forecasting, purchasing, scheduling. Facilities, layout, quality assurance. (2 units)

252. Introduction to Engineering Management II

Process facilitation. Integrating marketing, research, development, design, manufacturing, testing, field service, and support. MIS. (2 units)

253. Operating Systems

Production planning, scheduling, and control; quality assurance, performance standards; inventory control; design manufacturing communications, the management of product servicing. (2 units)

254. Introduction to Engineering Management III

Use of human resources. Innovation, leadership, motivation. Personal growth, job design, reaching agreement, communication. Managing for commitment. (2 units)

255. Accounting and Cost Control for Project Managers

Accounting records, debit-credit process, recording transactions, from transactions to statements, balance sheet, income statement, funds flow statement, costs, project cost controls. (2 units)

256. Finance and Budgeting for Engineering Managers

Profit planning, return on investment, accounting conventions, evaluation of economic alternatives, break-even analysis, tax environment, capital budgeting, cash flow, inventory policy, capital structure, security markets, financial controls, finance in general management. *Prerequisite: EMGT 255 or accounting knowledge.* (2 units)

257. The Business Environment

The economy; the price system; business cycles, money and banking, securities markets, business organizations, the corporation, business functions; marketing technology, finance, and operations. (2 units)

261. Technical Products and Profits

Organizing a technical firm. A business plan. Integrating marketing, finance, design, manufacturing, and service systems. (2 units)

262. Regaining Global Competition

Accelerated technology transfer, innovation, lowered costs, and reduced time-to-market in fiercely competitive global enterprises. (2 units)

263. Marketing of Technological Projects and Systems

Product planning, marketing research, demand analysis, product strategies, service organizations, pricing strategies, inventory planning, distribution, a marketing plan, product life cycles, sustaining user–inside manager communications. (2 units)

264. Managing Research and Development

Role of R&D in corporate growth; unique characteristics of R&D management; financing applied research; measuring return on investment; planning for diversification; structure of R&D organizations; choice of an R&D portfolio; idea generation process; selecting projects and establishing objectives; developing technical personnel; motivation of personnel; technical assistance to R&D staff; planning, scheduling, and control; project budgets and controls; performance appraisal; leadership in research organizations. (2 units)

265. Advanced Project Management and Project Leadership

Role of project manager as leader. *Recommended sequence: EMGT 330, 265, and 312.* (2 units)

266. Stress Reduction and the Catalyst for Creativity

Stress as an inhibitor and a source for creativity at work and in everyday living. Effective means of identifying, channeling, and alleviating stress for the engineering manager. (2 units)

267. Interpersonal Relations in Engineering Management I

Dynamics of human interaction and communication. Personal communication styles; new patterns of exchange and new approaches to interfacing with others. (2 units)

268. Interpersonal Relations in Engineering Management II

Continuation of EMGT 267. (2 units)

269. Human Resources Development and the Engineering Manager

Concepts of human resource management, the meaning of work, the individual and the organization, growth and learning, the manager's role in career/life management, human resource strategies. (2 units)

270. Effective Oral Technical Presentations

Role of communications, persuasive communications, speaking as a meeting leader, substitutes for reading speeches, purposes and effects, selling ideas to one or more persons, how to make meetings work. (2 units)

271. Effective Written Technical Communication I

Cluster writing; pyramid technique; audience analysis; opening, body, and end of text; technical correspondence; abstracts and summaries; presentation patterns for reports and proposals; proposal presentation. (2 units)

272. Effective Written Technical Communication II

Intensive writing practicum, overview of writing, mechanics of style, editing techniques, strategies for editing the work of others. *Prerequisite: EMGT 271.* (2 units)

273. Group Dynamics in Project Management

Managerial styles and their effect on group dynamics. Study of the literature on group processes. Managerial styles tested in a laboratory setting. (2 units)

274. Selecting the Technical Team

Manpower planning, caliber aspirations, locating potentials, testing, interviewing, legal pitfalls, pre-employment screening, employee processing orientation. (2 units)

275. Innovation, Creativity, and Engineering Design

Research, exploratory development, advance development, engineering development; the process of discovery; changing the status quo; recognizing a need; identifying creative talent; tradition vs. innovation; risks involved with new concepts; encouraging change; technological feasibility; manufacturing methods; inventions and their applications; marketability; the environment for innovation; creativity and the reward system; assertiveness training and creativity. (2 units)

278. Computer Systems for Project Scheduling and Control

Specification and configuration of computer-based systems for management applications. Methods for costing system hardware and software and for assessing computer performance. Trade-off analysis of comparative computer configurations. (2 units)

279. Management of Computer-Based Information Systems

In-depth coverage of the problems in managing computer-based information systems. Definition, evaluation, installation, and continuing management of EDP systems. Issues of planning and control; the organizational impact of computer systems. (2 units)

280. Systems Analysis for Computer-Based Information Systems

Detailed design and specification of computer-based management information systems. Existing systems, economic and organizational analyses of alternatives, and tools for determining user requirements. (2 units)

283. Engineering Venture Management

All facets of developing and starting an engineering project venture. Class works as a team to develop one new engineering business venture considering behavioral, marketing, financial, manufacturing, engineering, and administrative aspects. (2 units)

288. Management of Quality Assurance

Integrated analysis of the quality assurance function. Quality engineering sampling, inspection, failure analysis, and preventive maintenance. (2 units)

289. Total Quality Control

Quality control programs. Integration of quality in research, design, development, manufacturing, and other operations. (2 units)

290. Logistics Systems Analysis

Integration of inventory, transportation, order processing, warehousing, material handling using manual or computer systems. Facility location for optimization. (2 units)

291. Management and Methods in Reliability

Concepts in reliability as they apply to the efficient operation of an industrial system. (2 units)

293. Advanced Production Management

Examination of responsibilities of production manager in the technological enterprise for providing finished goods to meet the quality, price, quantity, and specification needs of the marketplace. Functions of production manager. Quantitative approach to decision making in production management. (2 units)

294. Management of Engineering Proposal Activities

Government procurement process, phases of procurement, procurement of large systems, request for proposal, and producing a winning proposal. (2 units)

295. Project Plan—Risk Management

Managerial decision making in project management under conditions of varying knowledge about the future. Decisions relying on certainty and decisions based on probabilities and made under risk. Situations in which there is no basis for probabilities; decisions made under conditions of uncertainty. Use of applications of decision theory to help develop strategies for project selection and evaluation. (2 units)

299. Research M.S. Thesis/Special Problems

(1–7 units)

301. Process Facilitation for Collaboration

Further practice in facilitation with emphasis on collaboration, group consensus, and joint production of a single document on managing. (2 units)

302. Network Leadership

Introduces concept of the leader as consultant and expert in problem solving in group situations. Stresses importance of goals, continuous change, and high achievement in global competition. (2 units)

303. Collaborative Action Learning

Importance of a coalition attitude and functioning as a group to solve contemporary complex issues. Concept of continuous learning through problem solving and critique. (2 units)

304. Sustaining High-Achievement Careers

Discusses problems and issues involved with a lifetime career in a single firm. Adaptability and morale issues. (2 units)

306. Improving Productivity I

Measurement of productivity. Historical approaches. Factors of major importance in contemporary society. Establishment of baselines for a program. (2 units)

310. Systems Management

Systems approach applied to management of technical organizations. Systems analysis, process flow, and information systems. Search for optimization of the organization as a system. Not a modeling course. (2 units)

311. Work Systems Design

Applications to real-time situations. Flow and operations studies. Student presentation of a system for class analysis. (2 units)

312. Computer-Aided Project Systems Management

Database and on-line entry and inquiry for scheduling and control and project report generation. (2 units)

315. Computer Process Control

Analysis and design of computer-based process control systems. Theory and practice of computer application: methods of automatic data acquisition, signal conditioning, process modeling, and optimization techniques. (2 units)

316. Computer-Aided Manufacturing

Numerical control fundamentals, components, and systems; human-computer-machine interfaces; numerical control programming, mathematics, and optimization; computer-aided manufacturing systems. (2 units)

319. Human Interaction I

Individuals interacting in groups to solve problems. Discusses mix of electronic and personal elements to achieve goals. (2 units)

320. Human Interaction II

A close look at communications. Personal limits. Electronic interfacing. The role of communication skills, attitudes, knowledge level, and culture in the communication process. (2 units)

321. Inventions, High Tech, and the Law

Legal aspects of high-technology industries. (2 units)

326. Measuring and Evaluating Research and Development

Sustaining an innovative environment while monitoring and evaluating project achievement. The need for measurements. Relating to the rest of the organization. Coupling evaluation with individual researcher's personal growth. (2 units)

327. Integration of Research and Development with Manufacturing and Marketing

Improving the commercialization rate of research and development. Structures for integration. Creating supportive attitudes. (2 units)

330. Project Management Basics

Need for project management. Matrix organization. Project planning and control cycle. Planning parameters. Schedule, cost, and performance interfacing. Controls. Reviews. Corrective and preventive action. Reports. Audits. Documentation. (2 units)

331. Strategic Technical Management

Translating strategic plans into action plans and ensuring their implementation. Integration of a process that crosses all organizational boundaries. Performance objectives and priorities, change and discontinuities, managed growth, accelerated technology transfer. Analyzing competitive technical position, collecting and utilizing user/customer information, and change leadership. (2 units)

332. Software Engineering Economics

Goals, life cycle of software engineering. COCOMO model, cost effectiveness analysis, decision criteria, multiple-goal decisions, uncertainties, risk, and cost estimation. (2 units)

333. Computer-Aided Project Management Scheduling and Control

Use of a macrocomputer database for scheduling, control, and information integration. (2 units)

337. Microcomputers in Project Management

Matching available software with the information and monitoring needs of the project environment. The concept of project overhead. Diminishing returns. (2 units)

339. Quality Issues in Managing Software

Defects: detection, removal, insertion. Assigning responsibilities. Quality and schedules. Developing quality skills. Zero defects. (2 units)

340. Managing Software Projects

Application of project management techniques to software projects. (2 units)

341. Software Project Issues

Measurement, estimating, standard data, projecting costs, system models, utilizing cost models, and quality control. (2 units)

360. Current Papers in Engineering Management

(2 units)

362. Topics in Engineering Management

Open to students with a minimum of 10 quarter units of course work toward the Engineering Management degree. (2 units)

363. Seminar: Managers, Leaders, Facilitators, Integrators

(2 units)

364. Seminar: Managing for Collaborative Action

(2 units)

365. Seminar: Managing and Motivating

(2 units)

366. Seminar: Managing to Improve Performance, Lower Costs, and Reduce Time-to-Market

(2 units)

367. Seminar: Managing Technical Professionals

(2 units)

368. Seminar: Project Management Issues

Classical project management requirements considered in the framework of cross-functional team problem solving. (2 units)

DEPARTMENT OF MECHANICAL ENGINEERING

Professors Emeriti: Eugene J. Fisher, R. Ian Murray, Richard K. Pefley
Professors: Mark D. Ardema *(Chair)*, Michel A. Saad, Terry E. Shoup
Associate Professors: Timothy K. Hight, Lee E. Hornberger
Assistant Professor: Lilia A. Sanchez
Adjunct Professors: Joseph T. Ma, P. K. Menon
John M. Sobrato Professor: Terry E. Shoup
David Packard Fellow: Lee E. Hornberger

Graduate courses in the Mechanical Engineering Department concentrate on four technical areas: (1) design and analysis of thermofluid systems for effective use of energy, (2) analysis and control of dynamic systems, (3) computer-aided design, and (4) manufacturing principles and practices. In addition to courses in material science, several courses in engineering mechanics, which are offered by the Civil Engineering Department, are applicable to the master's degree in Mechanical Engineering. Educational efforts are channeled to expand the skills of prospective and practicing engineers not only in understanding fundamentals but also in developing competence in analyzing engineering systems.

UNDERGRADUATE COURSES

10. Introduction to Engineering Graphics

Principles of orthographic projection, dimensioning, sectioning; isometric and auxiliary views. Descriptive geometry applied to representation and visualization. Computer-aided design using engineering workstations. (4 units)

11. Materials and Manufacturing Processes

Material properties and changes of these properties during processing. Manufacturing processes and their use to produce various mechanical items. Laboratory. (5 units)

15. Introduction to Material Science

Physical basis of the electrical, mechanical, and thermal behavior of solids. Relations between structural and physical properties. Theory of dislocations, vacancies, and other defects and their effect on physical properties. Illustrations of the relationships among material selection, manufacturing processes, and design. Laboratory. *Prerequisites: MECH 11, Physics 6, and Chemistry 6.* (5 units)

114. Machine Design I

Decision making in the solution of problems. Stress and deflection analysis are emphasized in the first part of the course; strength criteria are considered in the second part. One or two open-ended design projects. *Prerequisites: MECH 15 and CENG 43.* (4 units)

115. Machine Design II

Continuation of MECH 114. The solution of practical mechanical design problems. Design of components to withstand static and fatigue loading. *Prerequisite: MECH 114.* (4 units)

121. Thermodynamics I

Properties of pure substances. Work and heat. First and second laws of thermodynamics. Application to fixed mass systems and control volumes. Irreversibility and availability. *Prerequisite: Physics 6.* (4 units)

122. Fluid Mechanics I

Fluid properties and definitions. Fluid statics, forces on submerged surfaces, manometry. Streamlines and the description of flow fields. Euler's and Bernoulli's equations. Mass, momentum, and energy analysis with a control volume. Laminar and turbulent flows. Loses in pipes and ducts. Dimensional analysis and similitude. Laboratory. *Prerequisite: CENG 42.* (5 units)

123. Heat Transfer

Introduction to the concepts of conduction, convection, and radiation heat transfer. Application of these concepts to engineering problems. *Prerequisites: MECH 121 and 122.* (4 units)

131. Thermodynamics II

Thermodynamic potentials and availability concepts. Thermodynamic cycles. Nonreactive mixtures. Reactive mixtures with emphasis on the thermodynamics of combustion and chemical equilibrium. Laboratory. *Prerequisite: MECH 121.* (5 units)

132. Fluid Mechanics II

Introduction to gas dynamics. Concepts of lift and drag. Mechanics of laminar and turbulent flow. Introduction to boundary-layer theory. Application to selected topics in lubrication theory, aerodynamics, turbomachinery, and pipe networks. *Prerequisites: MECH 121 and 122.* (4 units)

133. Thermofluid System Design

Evaluation and selection of thermofluid system components such as compressors, fans, heat exchangers, internal combustion engines, and turbines. Applications of mathematical, economic-cost techniques and availability analysis to the synthesis, design, and evaluation of thermofluid system projects. Emphasis on an actual design project. *Prerequisites: MECH 123, 131, and 132.* (4 units)

140. Intermediate Dynamics

Motion in rotating reference frames. Angular momentum of rigid bodies. Moments and products of inertia. Gyroscopic motion. *Prerequisite: CENG 42.* (4 units)

*141. Introduction to Linear Systems**

Fundamental characteristics of linear systems via analysis of simple electrical and mechanical models. Forced and natural response. Introduction to Laplace transforms and their use in mechanical vibrations, circuit analysis, and electromechanical systems such as AC/DC motors. Laboratory. *Prerequisites: MECH 140 and AMTH 106.* (5 units)

*142. Control Systems Analysis and Design**

Modeling of physical systems. Analysis of linear feedback control systems by classical methods. Synthesis and design of control systems that satisfy certain stability and time-response criteria. Introduction to analysis and design by state-space methods. *Prerequisite: MECH 141.* (4 units)

143. Electromechanical Systems and Components

Machine dynamics, transfer functions, and modeling of physical electromechanical systems. Applications and laboratory. *Prerequisites: MECH 142 and ELEN 50.* (4 units)

145. Introduction to Aeronautical Engineering

Basic design and analysis of atmospheric flight vehicles. Principles of aerodynamics, propulsion, structures and materials, flight dynamics, stability and control, mission analysis, and performance estimation. Conceptual and preliminary design of various aircraft. Offered every other year. *Prerequisites: MECH 121, 122, and 140.* (4 units)

151. Finite Element Theory and Applications

Basic introduction to finite elements; direct and variational basis for the governing equations; elements and interpolating functions. Applications to general field problems—elasticity, fluid mechanics, and heat transfer. Extensive use of software packages. Offered every other year. *Prerequisites: COEN 4 or 44 and AMTH 106.* (4 units)

160. Modern Instrumentation for Engineers

Introduction to design of experiments, instrumentation, data acquisition, error analysis, and report writing. *Prerequisites: English 182, MECH 122, and senior standing.* (4 units)

188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work experience relating to their academic field of study and career objectives. Alternate or parallel periods of classroom study with periods of training in industry and government. Work includes overall report on assignment activities. P/NP grading. May be taken twice. May be taken for graduate credit. Additional fees required. (2 units)

189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or a research project, etc., after completing the co-op assignment. Approval of department co-op adviser required. Letter grades based on content and presentation quality of report. May be taken twice. May be taken for graduate credit. (2 units)

190. Independent Study

Investigation of a mechanical engineering problem and presentation of the results. Arrangement with a faculty adviser is required. *Prerequisite: senior standing.* (2–4 units)

193. Computer Design Workshop

An interdisciplinary workshop for engineering, art, and communication students. Graphics computers and software. Students work in teams to explore solutions to important social problems, use the

* Undergraduate course open to graduate students as space permits and only with permission of the dean of the School of Engineering.

computer to illustrate solutions, and complete formal presentations of their findings. Limited enrollment.. (Also listed as Art 193 and COMM 193.) *Prerequisite: permission of instructor*

194. Advanced Design I: Tools

Design tools basic to all aspects of mechanical engineering, including computer design tools. CAD, finite element method, simulation, CAM/robotics, engineering economics, and decision making. Senior design projects begun. *Prerequisite: MECH 115.* (4 units)

195. Advanced Design II: Implementation

Implementation of design strategy. Detail design and fabrication of senior design projects. Quality control, testing and evaluation, standards and specifications, and human factors. *Prerequisite: MECH 194.* (4 units)

196. Advanced Design III: Completion and Evaluation

Design projects completed, assembled, tested, evaluated, and judged with opportunities for detailed re-evaluation by the designers. Final written report required. *Prerequisites: MECH 195 and English 182.* (4 units)

199. Directed Research

Investigation of an engineering problem and writing an acceptable thesis. Conferences as required. *Prerequisite: senior standing in mechanical engineering.* (2–4 units)

GRADUATE COURSES

202. Mathematical Methods in Mechanical Engineering

Analytic solution of ordinary differential equations. Fourier series. Analytic solution of linear partial differential equations by separation of variables. Numerical solution of ordinary differential equations by iterative and direct methods. Introduction to numerical solution of partial differential equations using explicit, implicit, ADI, and relaxation-type methods. Eigenvalue problems. Introduction to complex variables. (Also listed as AMTH 202.) (2 units)

203. Analytical Dynamics I

Virtual displacement and virtual work, D'Alembert's principle, Hamilton's principle, generalized coordinates, Lagrange's equations, treatment of constraints. Applications to central force motion, gyrodynamics, and other mechanical systems. *Prerequisite: MECH 140.* (2 units)

204. Analytical Dynamics II

Variational principles, Gibbs-Appell equations, Hamilton's equations, Hamilton-Jacobi theorem. Stability of motion. Impulsive motion. Systems with varying mass, special relativity, and other advanced topics. Applications to mechanical systems. *Prerequisite: MECH 203.* (2 units)

205. Introduction to Vibrations

Derivation of equations governing physical systems. Behavior of single- and multi-degree-of-freedom systems. Linearization, state-space formulation, and canonical forms. *Prerequisites: MECH 140 and AMTH 106.* (2 units)

207. System Design I

The use of electronics in the control of machinery. Characteristics of components. Transistors. Linear and digital integrated circuits. Transducers. Oscillators

and frequency-sensitive circuits. Power devices and considerations. *Prerequisite: MECH 141 or ELEN 100.* (2 units)

208. System Design II

Use of microprocessors in the control of machinery. Microprocessors and microcomputers. Assembly-language programming. Interface design. *Prerequisite: MECH 207.* (2 units)

209. System Design III

Use of digital computers for the simulation and control of systems of machines. Development of mathematical models for systems. Numerical integration methods. State variables. Computer programs for simulation and control. *Prerequisite: MECH 208.* (2 units)

210. Nonlinear Oscillations I

Phase plane and phase trajectories. Conservative systems. Discontinuous systems. State space. Stability. *Prerequisites: MECH 141 or 205 and AMTH 106.* (2 units)

211. Nonlinear Oscillations II

Lyapunov's direct method. Applications, including rigid-body motion. Computation of stability domains. Time-varying systems. Limit cycles and topological methods. Perturbation techniques. *Prerequisite: MECH 210.* (2 units)

214. Advanced Dynamics I

Partial differentiation of vector functions in a reference frame. Configuration constraints. Generalized speeds. Motion constraints. Partial angular velocities and partial linear velocities. Inertia scalars, vectors, matrices, and dyadics; principal moments of inertia. *Prerequisites: MECH 140 and AMTH 106.* (2 units)

215. Advanced Dynamics II

Generalized active forces. Contributing and noncontributing interaction forces. Generalized inertia forces. Relationship between generalized active forces and potential energy; generalized inertia forces and kinetic energy. *Prerequisite: MECH 214.* (2 units)

216. Advanced Dynamics III

Dynamical equations of motion. Linearization. Steady motion and motions resembling states of rest. Integrals of equations of motion. Determination of constraint forces and constraint torques. *Prerequisite: MECH 215.* (2 units)

217. Introduction to Control

Laplace transforms, block diagrams, modeling of control system components and kinematics and dynamics of control systems, and compensation. Frequency domain techniques such as root-locus, gain-phase, Nyquist and Nichols diagrams used to analyze control systems applications. *Prerequisite: AMTH 106.* (2 units)

218. Guidance and Control I

Modern and classical concepts for synthesis and analysis of guidance and control systems. Frequency and time domain methods for both continuous-time and sampled data systems. Compensation techniques for continuous-time and discrete-time control systems. *Prerequisite: MECH 217, 142, or consent of instructor.* (2 units)

219. Guidance and Control II

Continuation of MECH 218. Design and synthesis of digital and continuous-time control systems. Nonlinear control system design using phase plane and describing functions. Relay and modulator controllers. *Prerequisite: MECH 218.* (2 units)

220. Electromechanical Devices in Computer Peripherals I

Analysis and design of electromechanical devices used in computer peripherals (i.e., storage devices and printers). Overview of performance requirements; the theory of operation, modeling, and design. Emphasis on solution of practical industrial problems. *Prerequisites: COEN 4, ELEN 50, CENG 42, and AMTH 106.* (2 units)

221. Electromechanical Devices in Computer Peripherals II

Continuation of MECH 220. *Prerequisite: MECH 220.* (2 units)

223. Inertial Instruments

Operation and theory of gyroscopes, accelerometers, momentum devices, and star sensors, with emphasis on their respective sensing mechanisms and use in control systems. Physics of the operation of the instruments. Instruments built and tested. Techniques for "sizing" the instrument requirements from a user viewpoint. Effect of external environments and interfaces. *Prerequisite: consent of instructor.* (2 units)

225. Gas Dynamics I

Flow of compressible fluids. One-dimensional isentropic flow, normal shock waves, frictional flow. *Prerequisites: MECH 121 and 132.* (2 units)

226. Gas Dynamics II

Continuation of MECH 225. Flow with heat interaction and generalized one-dimensional flow. Oblique shock waves and unsteady wave motion. *Prerequisite: MECH 225.* (2 units)

227. Gas Dynamics III

Continuation of MECH 226. Emphasis on linearized flow and the method of characteristics for supersonic flow. Numerical techniques and methods of experimental measurements. *Prerequisite: MECH 226.* (2 units)

228. Equilibrium Thermodynamics

Principles of thermodynamic equilibrium. Equations of state, thermodynamic potentials, phase transitions, and thermodynamic stability. *Prerequisite: MECH 131 or equivalent.* (2 units)

230. Statistical Thermodynamics

Kinetic theory of gases. Maxwell-Boltzmann distributions, thermodynamic properties in terms of partition functions, quantum statistics, and applications. *Prerequisites: AMTH 106 and MECH 121.* (2 units)

231. Reactive Gas Dynamics

Fundamentals in equilibrium reacting flow. Modeling of quasi one-dimensional reacting flow through nozzles of propulsion systems, hypersonic wind tunnels, and shock waves. *Prerequisites: MECH 225 and 230.* (2 units)

234. Combustion Technology

Theory of combustion processes. Reaction kinetics, flame propagation theories. Emphasis on factors influencing pollution. *Prerequisites: AMTH 106 and MECH 131.* (2 units)

236. Conduction Heat Transfer I

Flow of heat through solid and porous media for steady and transient conditions. Consideration of stationary and moving heat sources. *Prerequisites: AMTH 106 and MECH 123.* (2 units)

237. Conduction Heat Transfer II

Application of heat transfer principles to transient situations. Moving boundaries and phase transitions. Introduction to numerical techniques. Finite difference formulations, stability, and relaxation methods. *Prerequisite: MECH 236.* (2 units)

238. Convective Heat and Mass Transfer I

Solutions of basic problems in convective heat and mass transfer including boundary layers and flow in pipes. *Prerequisites: MECH 123 and 266.* (2 units)

239. Convective Heat and Mass Transfer II

Application of transfer theory to reacting boundary layers, ablating and reacting surfaces, multicomponent diffusion. Introduction of modern turbulence theory to predict fluctuations and other flow properties. *Prerequisite: MECH 238.* (2 units)

240. Radiation Heat Transfer I

Introduction to concepts of quantum mechanics, black body behavior, and radiant heat exchange between bodies. *Prerequisite: MECH 123.* (2 units)

241. Radiation Heat Transfer II

Treatment of gaseous radiation in enclosures. Solutions of transfer equation in various limits and for different molecular radiation models. Gray and nongray applications. Mathematical techniques of solutions. *Prerequisite: MECH 240.* (2 units)

242. Numerical Methods in Heat Transfer

Numerical techniques applied to heat transfer problems. Mathematical models for steady-state and transient heat transfer. One- and multidimensional analysis. Comparison with analytical solutions. *Prerequisite: MECH 123.* (2 units)

266. Fundamentals of Fluid Mechanics

Mathematical formulation of the conservation laws and theorems applied to flow fields. Analytical solutions. The viscous boundary layer. *Prerequisite: MECH 122.* (2 units)

267. Inviscid Flow

Fundamentals in potential flows. Flows over cylinders and airfoils. Conformal mapping. Methods of source panels. *Prerequisite: MECH 266.* (2 units)

268. Computational Fluid Mechanics I

Introduction to numerical solution of fluid flow. Application to general and simplified forms of the fluid dynamics equations. Discretization methods, numerical grid generation, and numerical algorithms based on finite difference techniques. *Prerequisite: MECH 266.* (2 units)

269. Computational Fluid Mechanics II

Continuation of MECH 268. General coordinate systems. Multidimensional compressible flow problems, turbulence modeling. *Prerequisite: MECH 268.* (2 units)

270. Viscous Flow I

Derivation of the Navier-Stokes equations. The boundary layer approximations for high Reynolds number flow. Exact and approximate solutions of laminar flows. *Prerequisite: MECH 266.* (2 units)

271. Viscous Flow II

Continuation of MECH 270. Similarity solutions of laminar flows. Separated flows. Fundamentals of turbulence. Introduction to numerical methods in fluid mechanics. *Prerequisite: MECH 270.* (2 units)

273. Designing with Plastic Materials

Mechanical, chemical, and thermal properties of engineering plastics and elastomers. Materials evaluation. Design of plastic bearings, gears, and housings. Design for creep. *Prerequisite: CENG 43.* (2 units)

274. Processing Plastic Materials

Casting, compression, and transfer molding of thermoset plastics. Thermoforming, extrusion, rotational and injection molding of thermoplastics. Secondary operations for plastics. Design for manufacturing of plastics. *Prerequisite: MECH 273.* (2 units)

275. Design for Competitiveness

Overview of current design techniques aimed at improving global competitiveness. Design strategies and specific techniques. Group design projects in order to put these design ideas into simulated practice. *Prerequisite: consent of instructor.* (2 units)

281. Fracture Mechanics and Fatigue I

Fracture mechanics evaluation of structures containing defects. Theoretical development of stress intensity factors. Fracture toughness testing. Relationships among stress, flaw size, and material toughness. Emphasis on design applications with examples from aerospace, nuclear, and structural components. *Prerequisite: consent of instructor.* (2 units)

282. Fracture Mechanics and Fatigue II

Materials and environmental factors governing fatigue life of structures. Fatigue initiation. Application to mechanical design. Fatigue crack propagation analysis using fracture mechanics approach. Corrosion fatigue and stress corrosion cracking. Relationship between nondestructive inspection capability and fatigue life. Emphasis on design applications. *Prerequisite: MECH 281.* (2 units)

283. Friction and Wear of Materials

Influence of material properties on surface interactions. Friction and wear. Types of wear including adhesive, abrasive, and others. Overview of solid film and boundary lubrication, lubricants, and their properties. *Prerequisites: MECH 15 and 132.* (2 units)

284. Computer-Aided Engineering

An overview of some typical hardware and software utilized in computer-aided engineering. Topics include PCs, workstations, mainframes, networks, file servers, output peripherals, system management, word processing, spreadsheet, database management, computer-aided drafting, computer-aided design, solid modeling, finite element analysis, and software and data integration. IBM PCs and HP 720 workstations used for hands-on experience. (2 units)

286. Hydrodynamic Theory of Lubrication

Derivation of the Reynolds equations and introduction to gas bearings. Incompressible slider and journal bearings, foil bearings, and numerical solutions of the Reynolds equation. *Prerequisites: MECH 122, 132, and 271.* (2 units)

287. Hydrodynamic Bearings Design

Principles and procedures for the design and analysis of gas bearings (i.e., journal and slider bearings). Application of gas bearings in computer peripherals such as disk files and tape drives. *Prerequisite: MECH 286.* (2 units)

288. Energy Conversion I

Introduction to nonconventional methods of power generation using solar energy, thermoelectric effect, and fuel cells. Description of the physical phenomena involved, analysis of device performance, and assessment of potential for future use. *Prerequisite: MECH 121.* (2 units)

289. Energy Conversion II

Discussion of magnetohydrodynamic power generation, thermionic converters, and thermonuclear fusion. (MECH 288 is not a prerequisite.) (2 units)

292. Theory and Design of Turbomachinery

Theory, operation, and elements of the design of turbomachinery that performs by the dynamic interaction of fluid stream with a bladed rotor. Emphasis on the design and efficient energy transfer between fluid stream and mechanical elements of turbomachines including compressors, pumps, and turbines. *Prerequisites: MECH 121 and 122.* (2 units)

293. Special Topics in Manufacturing and Materials

(2 units)

294. Special Topics in Mechanical Design

(2 units)

295. Special Topics in Thermofluid Sciences

(2 units)

296. Special Topics in Dynamics and Control

(2 units)

297. Seminar

Discrete lectures on current problems and progress in fields related to mechanical engineering. P/NP grading. (1 unit)

298. Individual Study

By arrangement. (1–6 units)

299. Thesis

By arrangement. (1–9 units)

301. Noise and Vibration Control and Monitoring I

Analysis of noise and vibration generation; effects on people and machinery. Applications to design of noise reduction systems. *Prerequisite: MECH 151 or 205.* (2 units)

302. Noise and Vibration Control and Monitoring II

Continuation of MECH 301. *Prerequisite: MECH 301.* (2 units)

304. Design and Mechanics Problems in the Computer Industry

Design and mechanics problems related to computer peripherals. Dynamics of disk interface, stresses and vibrations in rotating disks and flexible disks. Actuator design, impact and nonimpact printing, materials and design for manufacturability, role of CAD/CAM in design. *Prerequisite: consent of instructor.* (2 units)

307. Mechanics of Flexible Bodies

Euler and Rodriques parameters, screw motion, angular velocity matrix, centrobaric bodies, torque-free motion, cryostats, lumped mass models of spacecraft, finite-element methods for large flexible spacecraft. *Prerequisite: MECH 141 or 205.* (2 units)

308. Thermal Control of Electronic Equipment

Heat transfer methods to cool electronic equipment. Contact resistance, cooling fins, immersion cooling, boiling, and direct air cooling. Use of heat exchangers, cold plates, and heat pipes. Applications involving transistor cooling, printed circuit boards, and microelectronics. *Prerequisites: MECH 122 and 123.* (2 units)

315. Advanced Digital Control Systems I

Introduction to digital control systems design. Mini- and microcomputer application in industrial control. Analog-to-digital and digital-to-analog converters. Discrete-time systems, state-space representation, stability. Digital control algorithms, optimal tuning of controller gains. Finite-time settling control. Controllability and observability of discrete-time systems. *Prerequisite: MECH 142 or 217.* (2 units)

316. Advanced Digital Control Systems II

Continuation of MECH 315. Linear state vector feedback control, linear quadratic optimal control. State variable estimators, observers. System identification, model reference adaptive systems, pole-placement control. Minimum variance control, tracking and regulation problems. Adaptive control. *Prerequisite: MECH 315.* (2 units)

323. Modern Control System Design I

Design of control systems with multiple-input multiple-output plants containing multiple sensors and actuators using state-

space and optimal control techniques. Computational methods for design of control systems using conventional and optimal techniques. *Prerequisite: MECH 142 or 217.* (2 units)

324. Modern Control System Design II

Continuation of MECH 323. Numerical solution for optimal control system designs using first- and second-order gradient techniques. Statistical design approaches: time and frequency domain techniques, filtering, and estimation. *Prerequisite: MECH 323.* (2 units)

325. Computational Geometry for Computer-Aided Design and Manufacture I

Analytic basis for description of points, curves, and surfaces in three-dimensional space. Generation of surfaces for numerically driven machine tools. Plane coordinate geometry, three-dimensional geometry and vector algebra, coordinate transformations, three-dimensional curve and surface geometry, and curve and surface design. *Prerequisite: consent of instructor.* (2 units)

326. Computational Geometry for Computer-Aided Design and Manufacture II

Continuation of MECH 325. Composite curves, splines, and surfaces. Clipping, hidden line strategies, light sources, and shadows. *Prerequisite: MECH 325.* (2 units)

329. Introduction to Intelligent Control

Intelligent control, AI, and system science. Adaptive control and learning systems. Artificial neural networks and Hopfield model. Supervised and unsupervised learning in neural networks. Fuzzy sets and fuzzy control. (Also listed as ELEN 329.) *Prerequisite: MECH 324.* (2 units)

330. Structure and Properties of Modern Materials I

Atomic and crystal structure, bonding defects, phase equilibria, rate processes, and reactions, as related to the mechanical, electrical, magnetic, thermal, optical, and chemical properties of metals and semiconductors. For all engineering disciplines. *Prerequisite: MECH 15.* (2 units)

331. Structure and Properties of Modern Materials II

Structure and composition of polymers and how those relate to the ultimate properties of polymers; viscoelastic behavior, mechanical, thermal, electrical, and optical properties; strengthening; degradation; flammability and toxic effects. *Prerequisite: MECH 330.* (2 units)

332. Structure and Properties of Modern Materials III

Crystalline and glassy ceramic materials; defects; phase-equilibrium diagrams; nucleation; grain growth, sintering and vitrification; mechanical, electrical, magnetic, optical, and thermal properties; structure and properties of composite materials. *Prerequisite: MECH 331.* (2 units)

337. Robotics I

Overview of robotics: control, AI, and computer vision. Components and structure of robots. Homogeneous transformation. Forward kinematics of robot arms. Denavit-Hartenberg representation. Inverse kinematics. Velocity kinematics. Manipulator Jacobian. Singular configurations. Kinematic configurations of some common manipulators. (Also listed as ELEN 337.) *Prerequisite: MECH 324 or consent of instructor.* (2 units)

338. Robotics II

Euler-Lagrange equations. Dynamic equations of motion of manipulators. Task planning, path planning, and trajectory planning in the motion control problem of robots. Joint-based control. Linear control of manipulators. PID control and set-point tracking. Method of

computer-torque in trajectory following control. (Also listed as ELEN 338.) *Prerequisite: MECH 337.* (2 units)

339. Robotics III

Intelligent control of robots. Neural networks and fuzzy logic in robotic control. Selected topics of current research in robotics. (Also listed as ELEN 339.) *Prerequisite: MECH 338.* (2 units)

340. Introduction to Direct Access Storage Devices

Introduction to direct access storage devices including flexible and rigid disk drives. Overview of magnetic and optical recording technology emphasizing their similarity and differences and basic principles of operation. Device components technology including head, disk, positioning actuator, drive mechanism, drive interface, and controller. *Prerequisite: consent of instructor.* (2 units)

341. Direct Access Storage Devices

Design and analysis of direct access storage devices used in computer peripherals. Design and analysis of device components: drive spindle, drive mechanism, spindle velocity control, head positioning mechanisms, drive motor. Principles and design of linear and rotary actuator including voice coil motor and optimization. Shock and vibration problems in storage devices and air cooling. Device testing and manufacturing consideration. *Prerequisites: MECH 123, 140, 142, and 340.* (2 units)

343. Engineering Experimentation

Design and analysis of engineering experiments, with emphasis on practical applications. Review of statistical tools and statistical distributions. Organization of experiments to obtain statistically significant data. Experimental techniques and methods for the analysis of data. Overview of sensing techniques and selection of instruments based on resolution, accuracy, and measurement errors. *Prerequisite: AMTH 108.* (2 units)

344. Mechanical Aspects of Optical Systems

Fundamentals of optics. Optical materials, design, and testing. Mounting of lenses, mirrors, and prisms. Applications, including large optical devices. *Prerequisite: consent of instructor.* (2 units)

345. Modern Instrumentation

Fundamentals in computer-based data acquisition and control. Principles of operations of components in a data acquisitions system. Data domains and interdomain conversion of data. Experiments involving measurements and control of equipment. (2 units)

350. Composite Materials I

Design, analysis, and manufacturing of composite materials. Characterization of composites at the materials and substructural levels. Hyperselection. Manufacturing technology and its integration with design methods. Case studies. *Prerequisite: consent of instructor.* (2 units)

351. Composite Materials II

Composite material design at the structural level. Fabrication methods. Design for damage tolerance, durability, safety, and certification. Transfer of loads. Case studies. *Prerequisite: MECH 350.* (2 units)

352. Automation and Computer-Integrated Manufacturing I

Fundamentals of manufacturing automation. Production economics. NC machines. Part programming. APT, DNC, CNC. Adaptive control. High-volume production. Automated flow lines and assembly systems. Line balancing. Group technology. Computer-aided process planning. FMS. Robotics fundamentals, applications, and programming. Automated material handling and storage. *Prerequisite: consent of instructor.* (2 units)

353. Automation and Computer-Integrated Manufacturing II

Computer-aided quality control. Inspection and CMM. Computer process control. Programmable controllers. Automatic identification and data collection. Bar coding. Material requirement planning. Manufacturing resource planning. Just-in-time concepts. Computer-aided production management, scheduling, and control. Computer networks for manufacturing. Databases and CIM integration. Manufacturing simulation. Artificial intelligence in manufacturing. Case studies and group discussions. *Prerequisite: consent of instructor.* (2 units)

415. Optimization in Mechanical Design

Introduction to optimization: design and performance criteria. Application of optimization techniques in engineering design including case studies. Functions of single and multiple variables. Optimization with constraints. *Prerequisites: AMTH 106 and 245.* (2 units)

429. Optimization of Dynamic Systems I

Review of ordinary extrema. Calculus of variations. Maximum principle, optimal control of nonlinear sysems, state regulators. *Prerequisites: MECH 140 and AMTH 106.* (2 units)

430. Optimization of Dynamic Systems II

Continuation of MECH 429. Singular control, perturbation techniques, numerical methods. Differential games. Applications to mechanical engineering systems. *Prerequisite: MECH 429.* (2 units)

431. Aircraft Flight Dynamics and Performance

Equations of motion of aircraft flight under various assumptions. Quasi-static performance measures for various aircraft. Flight-path optimization. *Prerequisites: MECH 140 and AMTH 106.* (2 units)

432. Rocket and Spacecraft Dynamics

Equations of motion for vehicles with rapidly changing mass. Orbital mechanics. Optimization of trajectories and orbital transfers. Elementary orbit perturbation theory. *Prerequisites: MECH 140 and AMTH 106.* (2 units)

450. Airbreathing Propulsion

Thermodynamics and performance of ramjet, scramjet, turbojet, and turbofan engines. Aerothermodynamics of inlets, combustors, and nozzles. *Prerequisites: MECH 131 and 225.* (2 units)

461. Aerodynamics I

Thin airfoil theory and lifting line theory. Aerodynamic characteristics of airfoils. Vortex panel method. *Prerequisite: MECH 267.* (2 units)

462. Aerodynamics II

Airfoils in transonic and supersonic flows. Wings and wing-body combinations in compressible flow. *Prerequisite: MECH 227.* (2 units)

9

University Religious, Social, and Cultural Life

CAMPUS MINISTRY

Campus Ministry functions as a leaven within the University community so that the Living God may be magnified in all people: students, staff, faculty, and alumni. In keeping with the Jesuit tradition of developing the person, and with the ideal that all of us be people for others, Campus Ministry seeks to facilitate growth in individuals and the community by its presence, programs, and services.

The Campus Ministry staff reflects the reality of the Church today: a team of men and women—lay, religious, clergy—who encourage all members of this community to deepen their religious commitment in "the service of faith, of which the promotion of justice is an absolute requirement" (Decree 4, 32nd General Congregation of the Society of Jesus).

To attain this vision, Campus Ministry offers the University community a variety of programs: liturgies and other sacramental celebrations, retreats, counseling and spiritual direction, educational forums, interfaith sharing, and Bible studies. We collaborate with all segments of the community in the planning and execution of our programs.

In all of this, Campus Ministry is guided by the words of the prophet Micah: "This is what the Lord asks of you, only this: to act justly, to love tenderly, and to walk humbly with your God."

STUDENT LIFE

Participation in extracurricular activities is encouraged as part of the total development of the Santa Clara student. The primary educational objective in supporting student activities and organizations is to foster a community that is enriched by men and women of diverse backgrounds and wherein freedom of inquiry and expression enjoys high priority.

The following sections describe various aspects of student life and services. The *Student Handbook,* which may be obtained from the Office of the Dean of Students, contains more detailed information.

Student Conduct Code

As an institution of higher education rooted in the Jesuit tradition, the University is committed to creating and sustaining an environment that facilitates not only academic development but also the personal and spiritual development of

its members. This commitment of the University encourages the greatest possible degree of freedom for individual choice and expression, with the expectation that individual members of the community

- will be honest;
- will demonstrate respect for self;
- will demonstrate respect for others; and
- will demonstrate respect for law and University policies, regulations, their administration, and the process for changing those laws, policies, and regulations.

For a full description of the University's Student Conduct Code, judicial system, and disciplinary actions, please refer to the *Student Handbook*.

Athletics

The University maintains a well-balanced program of intercollegiate and recreational sports.

Intercollegiate competition for men is conducted in basketball, baseball, tennis, water polo, golf, soccer, crew, and cross-country. Intercollegiate competition for women is conducted in volleyball, basketball, softball, tennis, cross-country, soccer, crew, and golf. The participants in these sports compete against opponents of recognized national standing.

The University is a Division I member of the National Collegiate Athletic Association and the West Coast Conference.

Recreational sports involve participation in club sports, intramural, and recreational and fitness activities. The club sports program offers participation in men's boxing, volleyball, rugby, men's and women's lacrosse, women's field hockey, and swimming. Recreational and fitness activities are informal and instructional.

Student Organization

Association of Graduate Engineering Students (AGES) The Association of Graduate Engineering Students is open to all graduate engineering students. The organization presents a number of social, educational, and professional development events. For more information, contact the Office of the Dean, School of Engineering.

Student Media

KSCU-FM Radio KSCU-FM is managed and operated by Santa Clara students. It is designed to train students in broadcasting skills and to provide the University community with music, news, sports, and public service information.

The Santa Clara Review *The Santa Clara Review*, founded in 1869, is the University's literary magazine and the oldest college publication in the West. It

invites authors from every academic area to present their works for publication. Published three times a year, the magazine includes essays, journalistic pieces, short stories, poetry, and reviews.

The Redwood Having recently published its 91st edition, *The Redwood,* the University's student-produced yearbook, continues to record the annual story of the University. Throughout the years, *The Redwood* has earned a reputation for trendsetting and creativity in text, photography, layout, and graphic design.

The Santa Clara As the weekly campus newspaper, *The Santa Clara* reports on current events, sports, entertainment, and people. Outstanding coverage and design recently earned *The Santa Clara* an award that placed it in the top sixth of the country's university papers. All students, both undergraduate and graduate, are welcome to join the staff of nearly 75 students who work in reporting, photography, graphic design, typesetting, advertising, and layout.

Student Clubs

Students can become involved in a number of the more than 80 academic, recreational, religious, social, ethnic, and political organizations active on campus. The Associated Students of Santa Clara University (ASSCU) registers undergraduate student groups on behalf of the University. For more information, contact Benson Center #1. Students interested in graduate clubs and organizations should contact the Office of the Dean.

STUDENT RESOURCES AND SERVICES

Listed below are the many service centers established to meet the needs of students. Each center provides a variety of programs to encourage personal growth.

Career Services

Career Services provides a variety of services to assist students in clarifying, planning, and achieving their career goals.

A professional staff of counselors offers career counseling to individuals and groups. Workshops are held regularly on career planning, which includes self-assessment, resume writing, interviewing, and job search strategies. Programs have been developed that bring professionals from various fields to present information about career opportunities. A special program of informational interviewing links students with alumni in a variety of fields.

Career Services maintains strong contacts with employers. Information on cooperative education is available, as well as listings of full-time, part-time, summer, temporary, and work-study jobs. More than 200 local, national, and international employers recruit on campus to fill employment needs. Career fairs also attract many employers to the campus. The center maintains an extensive file with names of contacts at employer organizations.

Counseling Center

The Counseling Center, located on the second floor of Benson Memorial Center, offers free professional counseling to all undergraduate and graduate students. Confidential psychological counseling in a supportive atmosphere is designed to help students attain greater self-understanding and become more personally effective. Some of the concerns that students discuss with counselors include stress, depression, sexuality, individual identity and family, friendship, and love relationships. The special issues of minority and international students are recognized. In addition to individual, couples, and family counseling, small groups and workshops on topics of general interest are frequently offered. Consultation and referral for faculty, staff, and alumni and training opportunities for graduate students in counseling are also available.

Students in crisis or with urgent needs can be seen immediately on a walk-in basis. Regular appointments are made through the receptionist, and clients can be seen within one week by calling 408-554-4172. Counseling hours are Monday through Friday, 8 a.m. to 5 p.m. and some evenings by appointment.

Center for Student Leadership

The Center for Student Leadership was established to provide a resource within the Division of Student Development to enhance leadership development opportunities for students. The center directly supports the goals of the University; particularly the goal to educate leaders of competence, conscience, and compassion. In the Jesuit tradition of excellence, the Center for Student Leadership is committed to the development of socially responsible leaders. The center has designed a comprehensive leadership education program that is dedicated to preparing students to assume leadership roles in the modern world.

Student Health Services

Student Health Services are located in the Cowell Center on campus. Students may see the Student Health Services medical staff by appointment or for drop-in services while the University is in session. Students may call the Health Center (408-554-4501) for a schedule of hours.

All full-time undergraduates and all full-time law students are required to pay an annual health fee of $168. This fee makes them eligible for all of the services at Cowell Health Center. Any students who choose SCU-sponsored health insurance must also pay the health fee and therefore become eligible for services at the center. Other students, including graduate students, may pay the $168 annual fee and use the center. Health insurance coverage for outside care or other special needs is available and required for all international graduate and undergraduate students and for all full-time undergraduate students. University health insurance charges may be waived upon proof of outside coverage received in writing delivered to the insurance coordinator at the center by the appropriate waiver date.

All students eligible for and those who elect to pay for Student Health Services are required to have a pre-entrance health examination. Additional information about health insurance coverage and pre-entrance examinations may be obtained from Student Health Services.

Student Resource Center

The main focus of the Student Resource Center is to provide programs and services to students, academic departments, and other student development departments in order to build bridges to increase the academic success and full participation of all populations within the University community. Resource areas within the center include

African American Student Resources
Asian Pacific American Student Resources
Chicano Latino Student Resources
Disabled Student Resources
International Student Resources
Native American Student Resources
Off-Campus Student Resources
Re-entry Student Resources
Women Student Resources

Services and activities supported by the Student Resource Center include

- enhancing students' academic success and social involvement and progress;
- assisting students in effectively expressing their needs and concerns;
- creating opportunities for students' personal growth, responsibility for actions, and motivation and leadership development;
- providing opportunities for learning about the values and beliefs of one's own group and of other groups;
- providing necessary academic support services and accommodations for students with disabilities; and
- providing consultation to the University community regarding diversity issues.

Teaching and Learning Center

The Teaching and Learning Center, located in 247 Bannan Hall, offers a variety of programs to help students improve their learning skills and prepare for further education.

Two tutorial programs provide undergraduate students with assistance in many classes. Through the Individual Tutorial Program, students may arrange for personal tutoring. Drop-in tutoring is also available at different campus locations. Training in study skills takes place through workshops or in individual sessions at the center. Students receive help with time management, reading, and note taking and learn how to prepare for and improve performance on exams.

The center, by providing learning assistance in a supportive and encouraging environment, is especially useful to international graduate students who require special help in English.

The Teaching and Learning Center also assists juniors, seniors, and graduate

students planning to pursue graduate or professional studies select a school and secure financial aid. The center maintains a drop-in library of more than 800 graduate school catalogs and reference sources and arranges campus interviews with graduate school representatives from California and out-of-state schools. Each year the center sponsors a combined Graduate/Career Information Day with Career Services.

For national and international competitions for scholarships in which candidates must be officially nominated or endorsed by the University, the associate director, together with several members of the faculty, selects the nominees and arranges the endorsements. This office does not award fellowships, scholarships, or other financial assistance for study at Santa Clara or elsewhere.

The center also offers support for faculty through professional development programs such as workshops on teaching and learning and confidential individual evaluations of teaching.

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Facilities

ADOBE LODGE

Adobe Lodge is the oldest building on campus. Restored in 1981 to its 1822 decor, the lodge contains a presidential dining room as well as central and private dining facilities for faculty and staff.

BENSON MEMORIAL CENTER

The Robert F. Benson Memorial Center is the hub of campus life. The Benson Center is designed to meet the various needs of students, faculty, staff, alumni, and guests and to provide an environment for the education of the whole person that continues outside the classroom. Among the many services and facilities available are the Information Desk; Game Room; Brass Rail Cafe; Benson Cafeteria; Bronco Corral; Shapell Lounge; Down Under, a student-operated convenience grocery store; meeting rooms; Mission City Federal Credit Union; the bookstore; and post office. In addition, the offices of Campus Ministry, a number of offices of the Division of Student Development, and offices of student government and organizations are housed in the center.

CLASSROOM BUILDINGS

Nine classroom buildings house not only some 72 classrooms but also numerous administrative offices. Mayer Theatre and three Fine Arts buildings provide special classroom, rehearsal, and performance facilities.

COMPUTING FACILITIES

Santa Clara provides mainframe and personal computing facilities to support educational programs. Free noncredit short courses for both types of computers are offered periodically. Computer labs are typically open from 8 a.m. to midnight Monday through Friday, with hours slightly reduced on weekends.

The principal academic mainframe system is a Digital Equipment Corporation VAX-6610 running under the VMS operating system. The system operates 24 hours per day, and students have access from three public laboratories and through 30 dial-up ports.

PCs are concentrated in two general-purpose laboratories containing 150 IBM machines and various software packages for word processing, spreadsheet and database applications, and programming. Each PC can also function as a termi-

nal to the VAX. An additional 60 machines are contained in the Business School PC Classroom, Engineering PC CAD Lab, and in three smaller clusters serving the Chemistry, Mathematics, and Physics departments.

All registered students may use the PC labs and the central VAX without additional charge. More than 80 percent of the full-time faculty have a personal computer or workstation in their office, and computer use is a common element in all disciplines.

The School of Engineering provides an advanced graphics workstation facility containing 60 Hewlett-Packard 9000 high-end workstation computer systems with high-resolution color displays. These machines are located in two large classroom facilities, together referred to as the Engineering Design Center. They are used for computer-aided design (CAD) and analysis, computer graphics, and software development by the five engineering disciplines. In addition, the School of Engineering has several 386- and 486-based PCs and SUN workstations.

Most of the academic computers are connected by an Ethernet local area network (LAN), which provides high-speed communications among the various systems. Santa Clara is also a node on the Internet and BITNET wide-area networks, providing students and faculty with electronic mail, file transfer, and remote access communications to more than 3,000 nodes in the United States, Canada, Europe, Japan, and other countries throughout the world.

COWELL HEALTH CENTER

Cowell Health Center offers health services to students (see Page 120). The Cowell Center also houses the Public Safety Office and the University Human Resource Management Department.

DE SAISSET MUSEUM

The de Saisset Museum includes American, European, African, and Oriental art, as well as historically important objects from the early days of Mission Santa Clara. In addition to its permanent collection, it features special exhibitions of traditional, modern, and contemporary art.

Museum hours are Tuesday through Sunday, 11 a.m. to 4 p.m.; closed Mondays and holidays.

KIDS ON CAMPUS

Kids on Campus is the University child-care and preschool center for children of students, faculty, and staff members. The center is a cooperative under the supervision of a volunteer committee of parents with a small staff of paid employees and parent and student volunteers. It also is used occasionally for practicum experiences by students in psychology and education courses. The preschoolers benefit from a carefully developed program designed to meet their interests and to prepare them for kindergarten. Students are encouraged to visit the Kids on Campus facilities on the east side of the campus. Because space is limited, it is recommended that applicants sign up on the waiting list as soon as possible.

LEAVEY ACTIVITIES CENTER

Constructed in 1975, this unique air-supported dome is a popular multiuse facility that encompasses a variety of activities, recreational programs, intramurals, and events.

Included within the two acres of Leavey Activities Center are staff offices; the intercollegiate ticket office; basketball, volleyball, and racquetball courts; weight room, pool, sauna, steam room, and a cardiovascular area including Lifecycles, StairMasters, rowing machines, treadmill, NordicTrack, and Versaclimber.

Also located within Leavey Activities Center is Toso Pavilion, which includes a 5,000-seat arena for intercollegiate men's and women's basketball games and women's volleyball matches.

A monthly schedule of hours and activities is posted on the Leavey bulletin board. Students, faculty, and staff must present a validated ID card to the attendant upon entering.

LOUIS B. MAYER THEATRE

The 500-seat Louis B. Mayer Theatre is designed to provide the traditional proscenium stage common to most theatres, as well as an orchestra pit and thrust elevators that can be raised or lowered electrically. In a remarkably simple procedure, a wall is moved, a few seats are relocated, and the main theatre is reoriented to a new dramatic form that extends the stage into the auditorium so that the audience surrounds the action on three sides.

Mayer Theatre also has a special floor constructed for dance, as well as a large movie screen and film projector.

The Fess Parker Studio Theatre, housed within the Mayer Theatre complex, has no fixed stage or seating. Its black-box design, complete with movable catwalks, provides superb flexibility in an experimental setting.

MISSION SANTA CLARA

Mission Church marks the historic heart of the University. Adjacent to the beautiful Mission Gardens, the Church holds regular liturgical and sacramental services and provides an open place for quiet reflection and prayer.

NOBILI HALL

Nobili Hall provides on-campus housing for the University's Jesuit community. The four-story facility, named for John Nobili, first president of the college, contains a dining area and a chapel.

MICHEL ORRADRE LIBRARY

The collections and services of the Michel Orradre Library are designed to support the University's undergraduate and graduate academic programs.

OSCAR, the library's online catalog, is only one of a number of computerized

services that provide access to resources in Santa Clara's collections or through various forms of document delivery.

Orradre Library's collection, which dates from the founding of Mission Santa Clara, now contains more than 593,000 volumes and over 576,000 microforms. The library currently receives approximately 4,800 serial subscriptions and is a depository for U.S. and California government documents, which number almost 487,000 publications.

Staff at the reference and documents desks are available to help with research problems and assist students in using the library's collections and services; helpful publications and guides are always available. The Reference Department provides CD-ROM and online database search services, and the Circulation and Periodicals/Microforms departments assist with access to and borrowing of materials.

The library has open reading areas, individual carrels, small-group study rooms, copy facilities, and a personal computer laboratory.

During the academic year, the library is open seven days a week for a total of 106 hours. Most books circulate to undergraduates for 21 days and to graduate students for 42 days, but loan periods for heavily used materials on course reserve are limited to two hours or one, three, or seven days.

The Science Resource Center, located in the Daly Science Center, provides a noncirculating reference collection, current periodicals, and course reserve services for biology, chemistry, and physics.

RICARD MEMORIAL OBSERVATORY

Named after Jerome S. Ricard, S.J., Santa Clara's Padre of the Rains who was most famous for his sunspot theory of weather forecasting, the observatory now houses all of the University's audiovisual equipment and Media Services. Media Services offers downlink capabilities affording the University community the opportunity to participate in satellite broadcasts and teleconferences.

BUCK SHAW STADIUM

Originally built in 1962 for Santa Clara's varsity football and baseball programs, the 7,500-seat stadium is now home to the highly successful men's and women's soccer programs as well as baseball. The surrounding practice fields are the outdoor facilities for the remainder of Santa Clara's intercollegiate and intramural athletic programs.

Accreditations and Memberships

ONE HUNDRED AND FORTY-FIFTH YEAR
1995–96

Accredited by the Accrediting Commission for Senior Colleges and Universities of the Western Association of Schools and Colleges

Accredited by the American Assembly of Collegiate Schools of Business (Undergraduate and Graduate Programs)

Accredited by the American Bar Association

Admitted to Membership in the Association of American Law Schools

Accredited by the State Bar of California

Accredited by the Accreditation Board for Engineering and Technology (Undergraduate Civil, Computer, Electrical, and Mechanical Engineering)

Accredited by the California State Commission on Teacher Credentialing

Accredited by the American Chemical Society

Admitted to Membership in the National Association of Schools of Music

Admitted to Membership in the National Association of Schools of Theatre

Accredited by the American Association of Museums

Member of the American Council on Education

Member of the Council of Graduate Schools in the United States

Member of the American Council of Learned Societies

Member of the Association of Jesuit Colleges and Universities

Member of the Conference of Western Law Schools

Member of the College Entrance Examination Board

Member of the Association of American Colleges

Member of the Association of Independent California Colleges and Universities

Member of the Council for Advancement and Support of Education

Institutional Member of the American Mathematical Society

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Member of the Western Association of Graduate Schools

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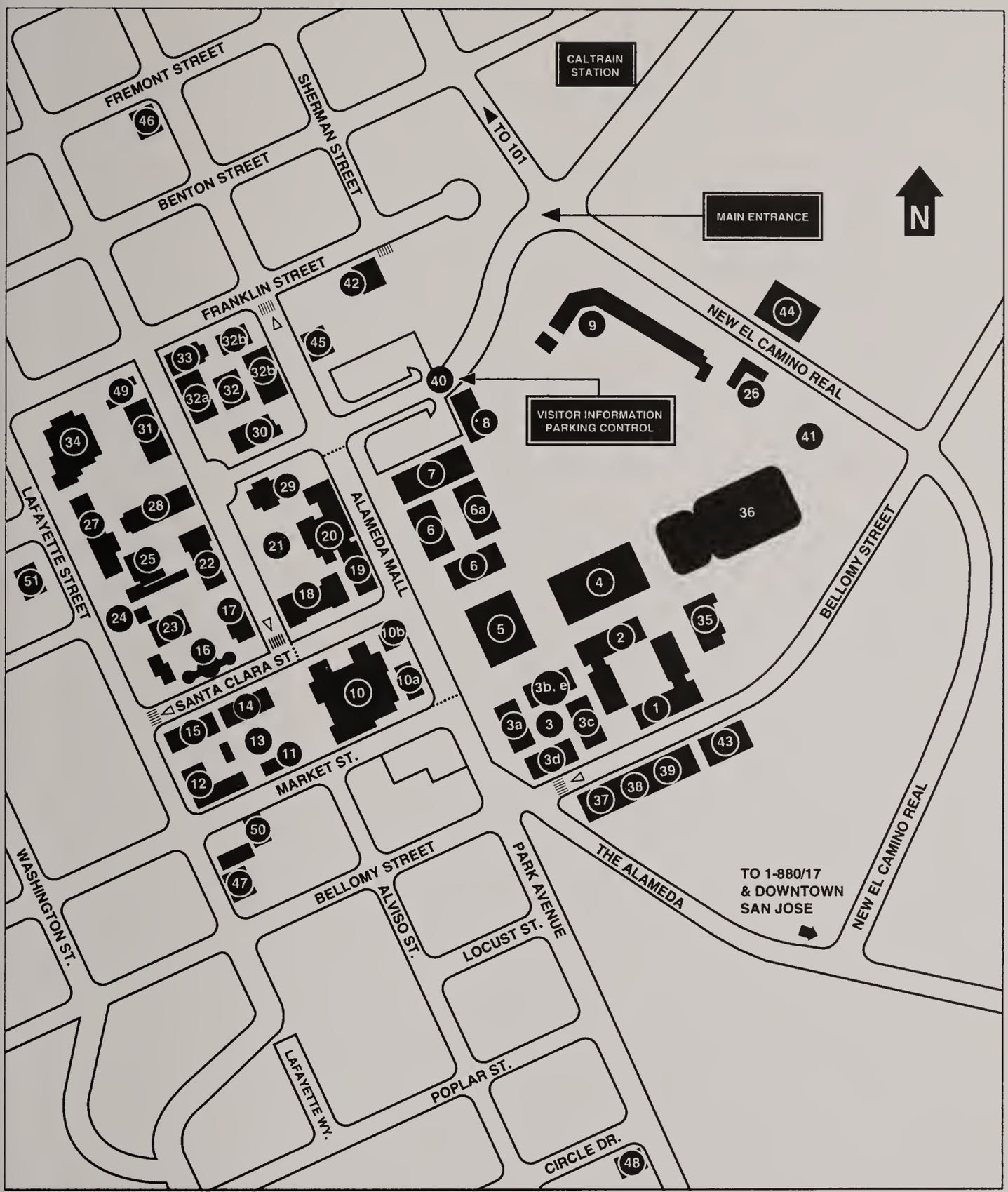
CAMPUS MAP

1. Sanfilippo Residence Hall
2. Campisi Residence Hall
3. Graham Residence Center
   - 3a. Strub Hall
   - 3b. Swig Hall
   - 3c. Hancock Hall
   - 3d. O'Neill Hall
   - 3e. Multicultural Center
4. Campus Tennis Courts
5. Orradre Library
6. Sullivan Engineering Center
   - 6a. Thomas J. Bannan Building
7. Bannan Hall Classroom Building
8. Field House
9. Buck Shaw Stadium
10. Benson Memorial Center
    - 10a. Campus Bookstore
    - 10b. Shapell Lounge
11. Swig Residence Hall
12. Dunne Residence Hall
13. Kennedy Mall
14. McLaughlin Residence Hall
15. Walsh Residence Hall
16. Ricard Memorial Observatory
17. Donohoe Alumni House
18. Kenna Hall–Leavey School of Business and Administration
19. Bergin Hall–School of Law
20. Heafey Law Library
21. Staff Lounge
22. St. Joseph's Hall
23. Varsi Hall–Admissions and Development Offices
24. Restrooms
25. Adobe Lodge–Faculty Club
26. University Day Care Center
27. Nobili Hall–Jesuit Residence
28. Mission Santa Clara
29. Walsh Administration Building
30. De Saisset Museum
31. O'Connor Hall
32. Daly Science Center–Science Library
    - 32a. Physics
    - 32b. Chemistry
33. Alumni Science Hall
34. Mayer Theatre
35. Cowell Health Center/Public Safety/Human Resource Management
36. Leavey Activities Center
37. Fine Arts Building
38. Dance Building
39. Music Building
40. Main Gates
41. Alumni Park
42. Law House
43. Casa Italiana
44. Physical Plant/Central Mailing/Central Receiving/Purchasing
45. Center for Applied Ethics
46. Alameda Hall
47. 569 Lafayette Apartments
48. Villa Apartments
49. Ramos Center
50. Eastside Project
51. Law Clinic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